

SOME EMINENT INDIAN SCIENTISTS & TECHNOLOGISTS

K. V. GOPALAKRISHNAN

Foreword

The National Council of Educational Research and Training (NCERT) has been deeply involved in the development of curriculum, textbooks and other related instructional materials at various levels of school education for the last four decades. This has influenced, directly or indirectly, the curriculum and instructional materials of all the States and Union Territories of the country which is a matter of great satisfaction for the Council.

Generally, it is found that despite a good curriculum and textual materials, students never get encouraged and motivated towards self-study. One of the reasons for this is our examination system, which tests only the knowledge imparted through textbooks. Thus, a very few students get motivated to read books other than textbooks. Moreover the reasons for not reading books outside the course can also be attributed to the non-availability of an adequate number of books for different age-groups of children at an affordable price. Although during the last few years, some work has already been initiated in this direction by the Council to overcome this deficiency, it is insufficient.

Taking all these aspects into consideration, the Council has initiated an ambitious and innovative project in the form of writing informative and enriching books for children of different age groups under different themes covering science and technology, languages, literature, social sciences, biographies, stories, culture etc. Under this project entitled, 'Reading to Learn', a series of books are being prepared for different age groups of children, in a simple and interesting style, in different subject areas by the Council. In the area of science and technology alone, more than thirty six books have already been developed under this project. We hope that we shall be in a position to publish a large number of books in Hindi and English in new and applied areas of science very soon.

In the development of books in scientific areas, we are seeking the cooperation and help of distinguished scientists, mathematicians and experienced teachers. Each book is given a final shape after careful scrutiny and thorough editing in terms of language, style and subject matter. These books are being published at cost price in order to make them accessible and affordable to all children in the country. Further, there is also a proposal to get some of these books translated in other Indian languages. It is hoped that this project will also be received well like the other projects of the Council initiated in the fields of curriculum, textbooks and supplementary reading materials.

I am thankful to Prof. K.V. Gopalakrishnan the author of 'Some Eminent Indian Scientists and Technologists' and Prof. R.D. Shukla, Head, Department of Education in Science and Mathematics, NCERT for coordinating the project.

We will appreciate the comments and suggestions of children, teachers and parents for making these books more useful and beneficial for the target group it is meant for

New Delhi May 2001

J.S. RAJPUT

Preface

The underpinnings of any great society are provided by its intangible beliefs, standards and attitudes. While the prosperity and strength of a nation easily strike the eye, it is the spirit and the value system of its people that form the base on which the physical edifice is built. And among the factors which contribute to the greatness of a nation, possibly the most important is the self-confidence of its people. People, proud of their past achievements and confident of their present capabilities, are well on the way to greatness, whatever might be their present difficulties.

The Indian nation, at present, faces its greatest handicap due to the lack of self-confidence. Of course, the primary cause of it is well-known namely, centuries of foreign subjugation which has undermined our spirit. But it has to be overcome by an effort and it is high time that we do it. If we look back, Indian civilization is one of the two oldest surviving ones in the world (the other is the Chinese). The Egyptian and Sumerian civilizations, once the contemporaries of our own, have long since disappeared into the limbo of history, while we have maintained a clear continuation of our traditions for several millennia. We had great literature and great learning centres such as the Nalanda University when Europe was still largely sunk in tribalism and America did not exist at all. And coming to the present, Indian scientists, engineers, writers etc. are making a powerful impact all over the western world and are highly regarded. The way Silicon Valley is gradually being dominated by Indians may lead to it being named Indian Valley! Hence there is no reason at all for us to feel diffident. No doubt great problems face us but there is also no doubt that we have the capacity to solve them.

Since Science and Technology are the dominant forces of the world now, our self-confidence is best built up by studying the achievements of our scientists and technologists in the recent past and being proud of them. After a long period of somnolence our intellectual powers started flowering again in the latter half of the nineteenth century. Apart from the obvious political and spiritual fields this awakening also extended to science and technology. The budding scientists and technologists of India during that period had to face far greater difficulties than their post-Independence successors. They were constantly needled by the British rulers about the inferiority of Indians and very little resources were made available for their work. But a sense of injured national pride made them press on. Apart from individual achievement, their goal was to awaken the pride of their countrymen by proving that they were the equals of their western counterparts.

The achievements of Indian science and technology are not negligible since Independence, though many of us may feel that much more could have been done. India is in the forefront in science and technology in the developing world. In fact, we are far more advanced in these fields than many developing nations richer than us. In Space Technology and Nuclear Energy we have proved that we can achieve great feats in the teeth of opposition from powerful nations.

Hence, the prime need of the hour is to strengthen the self-confidence and pride of our people. One of the best ways of doing it is by closely studying the lives and work of our great scientists and technologists and deriving inspiration from it.

It is my fervent hope that the brief biographies of the great Indian scientists and technologists contained in this book will contribute to stimulating young Indians to emulate their examples. Scientists and technologists have a powerful role to play in solving the manifold problems that our country faces and it is mainly in the hands of the young generation to lead our nation out of its difficulties and on to the path of prosperity and greatness.

K. V. GOPALAKRISHNAN

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A Few Words

This book is a small effort under the Project, 'Reading to Learn' of the National Council of Educational Research and Training. I was a little hesitant when Prof. J.S. Rajput, Director, NCERT, requested me to continue with the responsibility of getting science related books developed under the Project. My apprehensions were mainly due to awareness about the hectic schedule of my colleagues from the scientific community.

It has always been my endeavour to involve eminent intellectuals who have excelled in different disciplines of science and technology for this kind of work. I am of the opinion that only those scientists, who have experienced the thrill of discovery and research, can share their joy of achievement with children. I am grateful indeed to them for sparing some moments from their precious time for the benefit of youngsters of the country. Children are the precious treasure of a nation and I am overwhelmed and at the same time satisfied that our distinguished and busy scientists have happily agreed to make some meaningful effort for children. I am grateful to my scientist friends, for acquiescing to my request.

In preparing these books, our main objective has always been to present the subject matter in a manner that would attract and motivate the children to read. At the same time, the language of text is simple so that children do not encounter any difficulty in unravelling the mysteries of science while reading these books. I believe that reading these books would inculcate and develop in them the reading habits, arouse their curiosity and encourage them to experiment and satisfy their curiosity.

This project has been given new impetus by Prof, J. S. Rajput, Director NCERT for which I am thankful to him.

I am grateful to Prof. K.V. Gopalakrishnan who has accepted my request for writing this book. I am also thankful to Prof. R.D. Shukla, Dean (C) and Head, Department of Education in Science and Mathematics, the coordinator and editor of science books, for his sincere and dedicated efforts. Thanks are also due to Dr Shobha Laxmi Sahu for the assistance she has provided in the project.

I hope these books will facilitate development of the scientific temper from early childhood in our coming generations. It will create a sense of national pride through knowledge of latest scientific developments in our country and glimpses of the endeavours of our scientists.

R.C. MEHROTRA

Chairman

Reading to Learn Project (Science)

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I wish to express my deep appreciation and thankfulness for the efforts of Smt. Lakshmi Lakshmanan in typing the manuscript of this book and going through several stages of corrections.

About the Author

Dr K.V Gopalakrishnan has been teaching at the Indian Institute of Technology (I.I.T.), Madras since 1962. His speciality is internal combustion (I.C.) engines. He has done extensive research work on alternative fuels for I.C. engines including alcohols, hydrogen etc. and control of air pollution from engines. He has more than a hundred research publications to his credit.

Apart from his professional activities he has a wide range of interests and has published several articles on popular science topics and warfare in newspapers and magazines. Among the books he has written are “Inventors Who Revolutionised Our Lives”, and “A Treasury of Quiz Questions and Answers”.

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Some Eminent Indian Scientists and Technologists

1. Jagadish Chandra Bose *He could “talk” to Plants*
2. M. Visvesvaraya *Visionary Extraordinary*
3. Acharya P.C. Ray *‘Trail Blazer for the Indian Chemical Industry*
4. Srinivasa Ramanujan *A Nearly Lost Genius*
5. C.V. Raman *Very Little Spent, but Nobel Prize Won*
6. Meghnad Saha *Handicaps No Bar to Great Achievement*
7. Satyendra Nath Bose *A Name Immortalized*
8. Yellpragada Subba Row *His Obsession was Conquest of Diseases*
9. K.S. Krishnan *Sealing Wax and String Research*
10. Homi Jehangir Bhabha *The Father of the Indian Nuclear Programmes*
- U.S. Chandrasekhar *His Eyes were on the Stars*
12. Vikram Ambalal Sarabhai *. Pioneer of Our Space Programme*
13. Verghese Kurien *Father of the White Revolution*
14. M.S. Swaminathan *His Revolution was Green in Colour*
15. A.P.J. Abdul Kalam *Great Work is Possible in India Too*

PART A

India and the Scientific Revolution

1.

The Scientific-Industrial Revolution and its Impact on Mankind

In the famous story “Rip Van Winkle” by Washington Irving, the main character Rip sleeps through twenty years and wakes up to find the world changed beyond his recognition. If another human being had similarly slept through the last two hundred years and woken up in one of today’s industrially, advanced nations he would certainly have wondered if he had strayed into another planet. Cars, planes, electricity, telephones, computers and a thousand other things, that we take for granted without a second thought, would be utterly strange to him. Life for mankind has changed more in the past two hundred years than in all the previous five thousand years of recorded history. This revolution in our living condition has been brought about by just one facet of human activity, *SCIENCE* and its derivative *TECHNOLOGY*. Christopher Columbus took more than a month to cross the Atlantic Ocean. The supersonic jet airliner Concorde does it now in less than three hours. At the end of his voyage Columbus did not even know that

he was in a new continent! Today we can fix our position anywhere in the world through the GPS {Global Positioning System) within a few metres. A school student today knows more about the structure of the universe or the atom than the great Sir Isaac Newton did thanks to the advancement of knowledge. A few centuries' back huge numbers of people used to perish in India through recurrent famines. Today mercifully, thanks to the efforts of agricultural scientists and engineers, this spectre no longer haunts us, though our population is several times what it was in those days. A young Englishman embarking for service in England's colonies in the-eighteenth century was practically lost to his family for several years (if he returned at all from the perils of those days). Today he can be in touch with them on a minute to minute basis while being physically half a world away, thanks to the wonders of modern telecommunication. In the centuries past less than half the children born grew into adulthood. Small pox, tuberculosis, plague, malaria and typhoid decimated millions of adults too. But many of today's doctors haven't even seen these diseases in their practice, due to the miraculous advances in medicine and sanitation.

The list is endless. Once the accumulation of scientific knowledge gathered momentum incredibly swift advances took place in practically all aspects of human life. And the end is nowhere in sight. In fact, the pace of change is becoming ever swifter as we enter into the next millennium.

While the effect of scientific advancement of the material aspects of life is self-evident, what about its impact on human attitudes and behaviour? The fact is that human beliefs, habits and attitudes, which appear so inherent and fixed are capable of being powerfully altered by material factors. It is not only the intangibles like the conditioning by parents, teachers and preachers that affect human attitudes and behaviour. The physical conditions of life too profoundly affect them. In earlier centuries these were primarily natural factors like climate, geography (it is a well-known fact for example that mountain-dwelling people generally tend to be more war-like than dwellers of plains), food availability etc. But with the impact of science a whole new set of forces was unleashed. Spread of education and the dissemination of information by the mass media made it more difficult for ruling cliques to control the masses through selective indoctrination. Easy travel made people realise that the beliefs and value systems of their group were no god-given ones. Other societies functioned quite well with ones almost diametrically opposed to theirs. Education made women realise that they were no inferior to men in ability and hence they need not put up-with their subordinate status in society or ill-treatment from their spouses and in-laws. Traditions and age-old beliefs came to be challenged in the light of knowledge. The result of all this churning has been a progressive erosion in the power of ruling elites (based on various factors, political, religious, economic etc.) to control and exploit the masses. It is clear to all unbiased observers that the Scientific Revolution is gradually leading to a democratised society with prosperity for the entire population. In sum, it is the best thing to have ever occurred to mankind in history.

But human affairs are too complicated for any change to be an unalloyed success. The very power that science bestows on mankind has also led to serious problems, some foreseen and many unforeseen. It has led to ruthless exploitation of the earth's natural resources and heavy pollution of its air and water. Many species of our fellow living creatures, both plants and animals, have been hunted or exploited to the verge of

extinction. Wars have been made much more destructive through the terrible weapons that science has created. The weakening of long-held beliefs and emotional ties have led to social turmoils and tensions. Many of these fallouts of industrialisation have been so severe that some people have gone to the extent of condemning science as an unmitigated evil.

This of course is absurd. The harmful effects of science are due to our lack of wisdom and restraint and not due to science as such. While we have gained immensely in material power, the raw passions like greed and aggressiveness that underlie our nature remain untamed.

Hence what is needed to make the world safer is the taming of human passions through education, stressing compassion for all living things etc. and not by jettisoning science, one of the most valuable tools we have acquired in the course of our evolution. It makes no sense to throw the baby out with the bath water.

What is the prognosis for the future? It is pretty clear that the scientific revolution will roll on well into the future, with accelerating momentum as the nations of Asia and Africa, who constitute the majority of the population of the world but have played very little part in this process, join Europe and North America in scientific research and development. Prosperity is likely to spread to the poorer sections of the world. Nations will be bound closer together by better communications and economic interdependence. Some form of a world government is also certain to emerge.

But problems are also certain to multiply. If we are worried about the Greenhouse effect today what about the future when two-thirds of the world, called developing nations, also becomes as industrialised as the rest? Will the population explosion, triggered by the suppression of diseases by science, overwhelm some nations before rising living standards and educational levels can stabilise them?

It is difficult to answer these questions with certainty since man has unlimited capacity and short-sightedness to injure himself seriously but also has the capability to retrieve the situation before it is too late and prove the doomsayers wrong ! A case in point is food supply. Forty years back there was no dearth of Cassandra's who predicted that the fast-growing and underfed millions of the developing world would be decimated by famines in a few decades. But today the people of the developing world are on the whole better fed than forty years back (with a much larger population) and the apocalyptic disasters predicted by these pessimists did not come to pass. The reason? Spectacular rise in crop yields brought about by agricultural science and engineering in the recent decades. Similarly the war-shattered nations of Europe were expected by many to suffer and struggle for decades. But they recovered their pre-war levels of industrial production and rebuilt their cities within a single decade after the war, thanks to the efficiency of modern technology.

A heartening feature of the recent decades has been the rise of committed groups of people fighting for preservation of the environment and endangered species. Their dedicated efforts are gradually infusing concern for these issues among the general public and changing their attitudes. For example, a century ago many a European "nobleman" used to boast about the dozens of elephants and lions that he had shot for "sport" in Africa. Today the public would regard such a man with disgust as a sadist. Whalers and seal hunters are faced with organised boycott of their products. If public opinion becomes

sufficiently aroused and organised irresponsible industrialists who plunder natural resources and those wiping out our fellow living beings out of greed would find it impossible to function. It is the responsibility of all of us to build up such a public opinion. If science is applied with restraint and wisdom it can, in a few short decades, make the whole of mankind enjoy a quality of life that was never dreamt of in earlier centuries. This is the vision that must spur us all to action.

2.

How the Scientific Revolution Developed

Many aspects of human evolution remain profound mysteries to us, all our progress notwithstanding. Why is recorded history only about 5000 years old though the human beings of 10,000 or even 20,000 years back, according to scientists, were biologically just as well developed as the modern ones? Why did civilization originate in some parts of the world (Sumer, Egypt, and Indus Valley etc) and not in others? Why do 'civilization rise and fall with time apparently beyond human control? To these and many others may be added the latest *puzzle*: Why did Science, which has so revolutionised our lives, start its explosive growth only about four centuries back and not in the earlier millennia of our history? Why did it start in Europe and not in Asia or some other region? The fact is that we do not know the answers to these questions with any degree of certainty. Historians of science have come up with several hypotheses, but they are themselves the first to admit that they do not know for sure. Among the possible causes the historians list are the intellectual stimulation provided by the European Renaissance preceding the Scientific Era which encouraged people to think freely, unencumbered by previous beliefs and the spur to find a sea route to the Orient after the land route was closed in the fifteenth century (such an effort required accurate navigation and map making).

It must be noted that a thousand years back science in the Chinese, Indian and Arab societies was at a higher level than in Europe. Gunpowder, printing, the invention of the present numeral system and the beginnings of chemistry had their origins in these civilizations. But for unknown or complex reasons these achievements were not followed up vigorously as they were later in Europe.

Though its causes are unfathomable, the course of the Scientific Revolution is well recorded. It had its beginnings in sixteenth century Europe and has been gathering momentum ever since.

Great thinkers like Rene Descartes and Francis Bacon have cogently explained what is now clearly understood as the scientific method. The steps in this method are: (i) accurate observation and measurement of natural phenomena; (ii) a hypothesis or theory to explain these phenomena and (iii) a readiness to modify or discard the theory if facts observed subsequently can not be fitted into the theory. It is in this last requirement that science broke away most completely from the earlier human tendency to stick dogmatically to beliefs. This open-mindedness has been the key to the phenomenal success of science.

The first modern scientist based on the above criteria was undoubtedly Galileo Galilei (1564-1642). His stress on physical observation and measurement of natural phenomena guided the course of subsequent developments in science. The accurate observations and deductions of Galileo, Tycho Brahe and Johannes Kepler paved the way for Sir Isaac

Newton (1642-1727), whose theories on gravitation and mechanics form the first and one of the greatest triumphs of modern science. Newton showed that the laws of nature were the same throughout the universe (the earth was no special place!). Long observed but unexplained facts of astronomy and mechanics fell neatly into place in his grand scheme of things. The theory could even be put to use to locate planets of the Solar System like Uranus, Neptune and Pluto that could not be observed by the human eye and whose existence was hence never suspected. His was a colossal achievement by any standard and it is no wonder that after him the scientist came to command a respect and awe from the general public previously reserved only for great soldiers, monarchs and saints.

But the practical benefits of science did not immediately follow the scientific discoveries of the sixteenth and seventeenth centuries. The systematic application of science (The Industrial Revolution) started taking off only in the eighteenth century. The reason was that scientists were rarely interested in the commercial exploitation of their knowledge. By talent and temperament they were unsuited to it. That task had to be taken up by another set of people, the inventors, whose primary interest was the application of scientific knowledge to develop products useful to society. Later these gifted inventors often ran ahead of the scientists by building devices which worked splendidly, without fully understanding the basic scientific principles! The classic example is that of James Watt (1736-1819) who built his steam engines before the systematic development of the science of Thermodynamics. But gradually knowledge and application have fallen into step and today there is very little time gap between the two,

Once the power of science to change human condition was realised, progress has come in a torrent in the past two centuries. Governments and private industries willingly invested huge sums of money on research and development and the prestige of science attracted the best brains to it. Today there is hardly any aspect of human life untouched by the hand of science.

3.

How Europe Benefited from the Scientific Revolution

As mentioned in the last chapter it took some time for Europe to derive practical benefits from the achievements of its scientists of the sixteenth and seventeenth centuries. The impact of their work began to be felt in the latter half of the eighteenth century and the process really gathered irresistible momentum only after the conclusion of the Napoleonic Wars in 1815. But once it got underway the transformation was startling. Within a few generations Europe was changed beyond recognition.

The first great push was given by the steam engine invented by James Watt in 1769. Suddenly the power available to do work was increased several fold. A large steam engine could do the work of dozens of horses or hundreds of men. Hence manufacturing took giant strides. Factories to concentrate the efforts of hundreds of men followed. Coal and iron industries developed greatly to support these factories. The application of steam engines to power railway locomotives (1825) and large ships (1833) revolutionised travel and the transport of goods. The invention of the telegraph (1844) speeded up communication. The development of mass printing led to the spread of education and rapid dissemination of news. Agriculture too benefited. Productivity rose and agricultural

workers were freed to work in industries. The development of electrical power in the late nineteenth century gave an even greater push to the transformation. The invention of the automobile (1888) and the aeroplane (1903) gave unprecedented mobility to individuals.

What were the effects of these changes on European society? The standard of living rose dramatically for many. 'Population soared initially. European military power grew enormously. Small numbers of European soldiers and sailors proved strong enough to overwhelm huge numbers of non-Europeans (as we learned to our cost).

Perhaps the greatest benefit of the scientific revolution was the spread of education. All previous civilizations have been characterised by a small educated elite supported by a multitude of illiterate toilers. By leading to mass education and the production of enough goods and services to maintain the whole population in reasonable comfort, the Scientific Revolution is gradually leading to the first genuinely democratic and egalitarian society in the history. But the change has not been smooth, in Europe or elsewhere.

We Indians-justifiably feel angry about our colonial period when we were economically exploited by the British for their benefit. But during the first several decades of industrialisation the bulk of the European population was just as badly exploited as any colony! Children of under 10 years and women were made to work more than 12 hours a day in factories. Workmen had no defence against arbitrary dismissals. They were not covered against injury or death in the workplace. Their struggle to win the right to strike, reasonable working hours and conditions etc. was just as intense as many colonial struggles for independence. The rise of socialist and communist movements was the direct consequence of the excesses of industrialisation.

European nations, particularly those with a maritime tradition like Britain, Holland and France used their new found power to militarily spread themselves all over the world and economically exploit the non-industrialised people. The impact of European industrialisation was painful for the nations of Asia and Africa until they learnt to protect themselves by counter-industrialisation.

4.

How the Non-industrialised Nations Fared

Before the scientific era different regions of the world lived practically' isolated from each other. Apart from some sea-borne commerce and adventurous travellers Europe and Asia for example, might as well have existed in different planets, so little was their interaction. But with industrialisation the picture changed drastically. Steamships and railways made possible the mass movement of goods and people. The telegraph, the press and the telephone enabled speedy interchange of messages and ideas.

The rapid industrialisation of Europe created a huge thirst for raw materials like cotton, rubber, tin etc. The tremendous productive capacity built into its factories, far in excess of local needs, demanded outlets of protected overseas markets. The burgeoning population out-ran the capacity of local agriculture to feed them in many European nations and assured cheap import of food articles became a necessity.

All these pressures building up in industrialising Europe led to the next phase of history: Colonialism. Vast regions of Asia and Africa, rich in resources and potential markets but militarily weak due to their pre-industrial economies, attracted European nations like magnets. Industrialisation provided Europeans with weapons that were immensely superior to anything the “natives” had. Equally important, it had inculcated in them a sense of discipline and the habit of collective action which enabled small European armies to overwhelm numerically large but ineffective Asian armies. The upshot was that in the course of the eighteenth and nineteenth century’s vast portions of Asia and practically the whole of Africa passed under European control as colonies. The colonies were made to supply the colonial powers with industrial raw materials and food articles at cheap prices and made to import manufactured articles from the ruling imperial power.

European nations like Britain, Holland and France with long coast-lines and a maritime tradition had a natural advantage in the race for colonies. Other European nations like Germany and Italy which entered the race later due to geographical and political factors found the world pretty well parcelled out among the earlier colonial powers, particularly Britain and France. The resentment and tension that this situation generated was one of the main reasons for the outbreak of the First World War (from which the Second World War followed).

Britain was the dominant colonial power of this era. As an island nation wide open to the seas and with a proud maritime tradition it had an incomparable advantage over its rivals. In fact, it could even be said that the other colonial powers like France, Holland and Belgium could hold on to their colonies only because the British allowed them some share in the spoils.

Among the British possessions India was regarded as the “Jewel in the British Crown” and naturally too, since a region several times the area and population of Britain could be exploited as a source of raw materials and a protected market for British manufactured goods. British rule led to the introduction of railways, unification of the different regions of India, a network of schools and colleges to impart education etc. But the primary purpose of these measures was to strengthen British control over the country and facilitate its economic exploitation. Native industrialists were not encouraged and the educational system was designed to produce lower level personnel for the British administration. Colonial rule everywhere led to the gradual impoverishment of the people of the colonies. This fact is starkly brought out by the vast disparity in the standard of living of the colonial powers and the colonies at the end of the colonial period. India was the most glaring example of this.

An even more pernicious effect of colonialism was the loss of self-esteem on the part of the ruled. Colonial people subconsciously came to believe in the superiority of their rulers and in their own inferiority. This defeatist attitude has persisted to some extent even after their liberation.

It is a part of human nature to convince one’s self that one’s actions are prompted by altruism even when they are utterly selfish. The colonial powers came to believe that they were ruling the colonies only to benefit the “natives”. The British certainly took the cake in this respect. Their bards of Imperialism like Rudyard Kipling propagated the concept

of the “White Man’s Burden”, meaning that the white man had to sacrifice much to save the brown man from himself!

The only important nation to escape colonialism was Japan. The Japanese were forced to open their country to white traders by a squadron of warships led into the Tokyo Bay by Commodore Mathew Perry of the U.S. Navy in October 1853. The Japanese realised that they stood no chance against the mighty guns of his fleet and yielded. But they learned their lesson. In the subsequent decades they went all out to industrialise their nation. They freely interacted with the Europeans to learn their methods, without however compromising their basic national character. Within sixty years.. Japan became the equal of any colonial power and hence immune to colonial exploitation. Herein lies the lesson that Japan still holds out to the developing nations: “Modernise or you will be exploited. But you do not have to give up your basic national character and culture to achieve this.” It is a lesson that we Indians will always do well to remember.

5.

India and the Scientific Revolution

India, like almost all Asian and African countries, missed the Scientific Revolution. Two hundred years of domination and exploitation were the price we had to pay to learn its lessons. The first lesson is a positive one namely, science is necessary to raise living-standards and achieve an egalitarian society. The second is a negative one: If a nation fails to keep step with scientific progress it will be an easy prey to nations which have done so.

But India was not always laggard in scientific matters. A thousand years back Indian scientific knowledge was superior to Europe’s and European standard of living was no higher than India’s in the fifteenth or sixteenth centuries. In astronomy, medical science and mathematics Indian contributions outmatched those of Europe in ancient times. Five centuries before Christ Susruta performed plastic surgery in India, employing simple methods of anaesthesia and sterilisation of instruments. Charaka was a pioneer of the Ayurveda medical system 20 centuries back, when Europe had no systematic medical knowledge at all. Incredibly Aryabhatta in the sixth century A.D. discovered how lunar and solar eclipses are caused. He also worked out the value of π to the fourth decimal place. Brahmagupta of the seventh century is credited with introducing the concept of the “Zero”. Varahamihira, Bhaskara and Nagarjuna also made scientific contributions any nation could be proud of.

But somehow, Indian society failed to put its scientific knowledge to practical use. If it is any consolation, the other ancient civilisation of Asia, China, also trod a similar path by being far ahead of Europe in science and technology in ancient times but failing to capitalise on it.

After a slumber of several centuries India began to wake up as a result of its humiliating experience of colonialism. Indian thinkers realised how the power of science enabled a nation, a fraction of our size and population and located nearly half a world away to easily conquer and rule us for an extended period. Nationalism, the other great contribution of Europe to the world, was also really dependent on science to be effective.

Without modern means of communication and control large nations can not be held together or function cohesively.

Paradoxically, the colonial power also unwittingly contributed to this awakening. English education enabled Indian intellectuals to learn about the historical development of democracy in England and about the progressive views of great English thinkers like John Locke, David Hume, John Stuart Mill and others. They came to realise how big was the gap between what the British practised in their own country and what they did in India! Medical and biological sciences introduced by the British in our educational system clearly showed that there were no essential differences between the various races of mankind. None was inherently superior or inferior to the others. Western education also enabled our intellectuals to stand apart and dispassionately analyse the weaknesses of our society and suggest remedies. The railways, the telegraph and the popular press brought Indians together physically and emotionally to a degree never before possible.

The Indian reaction to colonialism took several forms. The most visible of course was the Freedom Movement. It also led to a Cultural Renaissance which brought to the attention of the masses India's ancient heritage and rekindled their pride and self-esteem.

Less noticed, but also very much present was the attempt to foster scientific education and research in India. Our intellectuals realised that we had to prove ourselves as capable as westerners in Science or we would never win their respect. Hence a dedicated group of Indian scientists laboured mightily in the period between 1857 and our Independence to prove that the Indian mind was second to none in science too.

The task was not easy. The country was essentially poor, with the majority of the population living at subsistence level. Little resource could be spared for scientific research. Even more importantly the colonial power did not wish to see India progress in science since it would undermine its domination. Hence these pioneers had to struggle against scarcity of resources and the hostility of the ruling power. It is a tribute to their spirit and perseverance that they achieved as much as they did under these conditions. They worked on shoe string budgets. Many school laboratories in Europe had equipment better than what they had to work with. But they did not falter or complain about our conditions (as many young men do today when the situation is far better). Their dream was not to shake off the dust of India and settle abroad. They believed that they had a duty to awaken the self-esteem of our masses through their scientific achievements. Many of the great figures of this period are briefly described in this book. They performed a great task, keeping the torch of science burning in the darkness of their period until a new generation of scientists could take over in the much more encouraging atmosphere after Independence.

6.

Science and Technology in Independent India

August 15, 1947 marked not only a new political era for India but also a sudden opening of new vistas for Indian scientists. Gone was the veiled hostility of the colonial administration to the advancement of Indian Science. On the other hand, the leaders of free India, led by Pandit Jawaharlal Nehru, were keen to promote scientific research and

spread the scientific temper among the masses. They were quite ready to lavish on this task resources which were beyond the imagination of pre-Independence Indian scientists.

Nevertheless, progress has not been easy to achieve. Our national literacy level at Independence was less than fifteen per cent. In the universities the stress was on arts, literature etc. and not on science since the system was meant to provide clerks and accountants to the British administration. As will be seen in the biographies that follow, many of the great names in pre-Independence Indian Science were forced to seek administrative jobs after graduating in science, which they had studied out of love. So little was the scope allowed for Indian scientists in that period.

How has India fared in this task since Independence? Undoubtedly, great progress has been made, but great lacunae also still remain. Post-Independence Indian governments took great efforts to spread elementary and higher education. The number of young students studying in our schools and colleges now is larger than the total population of most countries of the world! Chains of laboratories for research were established through agencies like the CSIR. Today we have one of the largest pools of trained scientists and technologists in the world. Our scientific capabilities are among the highest in the developing world, higher than many other developing nations economically better off than we are. Indian scientists and technologists who have settled in Europe or USA have achieved great success and are highly regarded in those nations.

But on the flip side, the same Westerners who admire our scientists and technologists working among them also wonder why a nation which can produce such able men is still unable to translate this innate ability into solid economic achievements. Why is this nation of gifted people still found in the lower range of almost all indices of development? Not only they, we also must wonder about this painful paradox! One reason widely advanced is our tight administrative control and procedural hurdles which hamper scientific work. A scientist requires freedom to pursue his ideas and the resources and conditions necessary for his work has to be arranged by another set of people trained in administration. The most seminal work in science is often done in an atmosphere which to the common man may appear very relaxed and even inactive. The atmosphere of a great European University for example is very different from that of their automobile plants or their banks. Scientists require a very different kind of handling from those doing set, routine tasks. Being new to the field of extensive scientific research we have still not fully learnt this lesson but it is essential to do it.

Another major lacuna is the absence of a strong industry-academic interaction. In the USA, for example, the electronic revolution was fuelled mainly by the research and enterprise of scientists in famous universities and research laboratories. Our industry and research institutions have to learn to work together for mutual benefit. The habit of relying on imported technology for even simple products has to be gradually given up. It is noteworthy that our most impressive post-Independence technical achievements have been in the fields of Atomic Energy and Space Technology, in which we were forced to work without any foreign collaboration at all. A solid industry-academic tie up is necessary for any nation to become technologically advanced.

In our efforts to become a fully industrialised society we are bound to meet the overt and covert opposition of the already advanced nations. After all, who likes to give up his advantages! New entrants to the field will have to pull themselves up to the level of the

advanced nations by their own efforts before being admitted to the group. It is a discouraging fact that except for Japan no other nation has succeeded in doing this in the post-war period. Subtle (and not so subtle!) resistance can be expected from the advanced nations in the future too, but our scientists and technologists must rise to the challenge in the service of their country.

In this task they can find great inspiration from the lives and work of earlier generations of Indian scientists who worked under much greater handicaps in the pre-Independence period. They can also draw inspiration from some outstanding scientists and technologists of the post-Independence era who have made sterling contributions to the advancement of Indian science and Indian economy. Brief life sketches of some outstanding members of both periods are given in the next part. It is fervently hoped that their examples will spur our young men and women to be equally effective in strengthening their country.

PART B

Some Eminent Indian Scientists and Technologists

1.

Jagadish Chandra Bose

He could “talk” to Plants

The idea that plants also react to stimuli such as electric shock, chemical irritation, excessive heat etc. in the same way as human beings, is difficult for us to comprehend. But they do so and the first scientist to establish this fact was Dr. Jagadish Chandra Bose, the earliest of the famous scientists that India produced in the pre-Independence days. So great was his understanding of the sensitivities of plants that his students used to half-seriously suggest that he could “talk” to plants.

J.C. Bose was also a rarity among scientists in another aspect. He was an original research worker in two completely unrelated fields, plants and radio waves. His research in the latter field paralleled that of his contemporary, Guglielmo Marconi. But Bose had the ascetic streak typical of many learned Indians. He pursued knowledge for its own sake and cared little for its commercial possibilities. But for this attitude he could have been the Father of Wireless Communication instead of Marconi.

J.C. Bose was born on 30 November 1858 in Mymensingh, in what is now Bangladesh. His father, Bhagavan Chandra Bose was a deputy magistrate. Bhagavan Chandra Bose was quite untypical for an Indian bureaucrat of those days. He deeply loved his native language and culture and had a profound sympathy for the poor among his countrymen. He spent considerable sums of his own money in starting industries and plantations to provide employment to them. But his managerial abilities did not match his idealism and his efforts failed, saddling him with heavy debts, a part of which passed on to his son Jagadish also. His efforts thus ended in failure, but it was a glorious failure. The memory of his father’s idealism and sympathy for his countrymen inspired Jagadish Chandra throughout his life.

Jagadish was educated at school in the Bengali medium until eleven years of age due to his father's intense cultural pride. This ensured that Jagadish, unlike his convent-school going contemporaries came into close contact with children from the working classes and also from various religious groups. This experience immunised him for life from caste, class and religious prejudices. From these children, close to the earth, he also acquired an abiding love for animals, plants and birds. Later it was to induce him to study plant behaviour in depth.

Jagadish was admitted to St. Xavier's School in Calcutta in 1869 and completed his schooling in 1875. Many of his schoolmates later recollected that Jagadish spent practically all his pocket money on tending plants and pets. He also came into contact here with a different class of boys from well to do families. But it was to have little effect on his own attitudes, already well set.

Jagadish joined St. Xavier's College in Calcutta and obtained a degree in science in 1879. The most noteworthy feature of his education in this college was the inspiration he received from Father Lafont, a superb teacher of Physics. By this time his father's financial state was quite grim mainly due to his failed attempts to help the poor. Jagadish proposed going to England to study for selection to the Indian Civil Service (I.C.S.J, the most coveted career in those days. Jagadish's intention however was to help his father through the high remuneration's of that service. But the patriotism of Bhagavan Chandra was stronger than his financial needs. He did not wish his son to spend his life in the service of the British. He wanted him to be a scholar, one who would impress his countrymen by his learning and not by his authority. He however agreed to an alternative suggestion that Jagadish came up with, to study Medicine in England since he could serve people through this profession. His financial troubles did not matter to Bhagavan Chandra in his ambition to give his son a superb education.

Jagadish started his studies in England in 1880. He completed successfully courses in Zoology and Botany. However, when he got into the regular medical courses an unexpected problem cropped up. The disease Kala-azar, which he had contracted years back in India, resurfaced. Expert treatment failed to cure him. He was advised by the doctors to give up medical education since they believed that the strong odours of the dissection rooms aggravated the disease. After some time of perplexity, Jagadish joined Christ's College in Cambridge University for a course in natural science. This prestigious college counted among its science faculty some of the best known names in their fields. In particular, Lord Raleigh was an inspiring teacher of physics and strengthened Jagadish's interest in the subject, already planted by Father Lafont. Lord Raleigh also proved to be an exceptionally kind-hearted teacher, helping Jagadish in many ways long after he ceased to be his student. Jagadish passed the Natural Science Tripos of the Cambridge University as well as the B.Sc. of the University of London in 1884. During this period he met Prafulla Chandra Ray (P.C. Ray) in London and they became fast friends. However, they probably could not have guessed then that they both would become honoured names in the history of Indian Science.

Jagadish left for India in 1885. He secured the post of Officiating Professor of Physics in the Presidency College of Calcutta. Here he came face to face with the petty treatment that Indians had to endure in their own country. Indians were paid only two-thirds of what Englishmen doing the same job were paid, and this in India, not England! Jagadish

Chandra Bose had too much self-respect to accept this. But his protest was novel. He worked enthusiastically at this job but refused to accept his salary, for three long years. Jagadish's father was in a precarious financial state and Jagadish himself had acquired a family by marrying Abala Bose in 1887, but it did not matter. He stuck to his guns, loyally supported by his wife, notwithstanding all the hardship that it entailed. Finally the administration relented and he received his full back pay. He had made his point.

Almost the first thing that Jagadish did after receiving his arrears was to pay off his father's debts. Fortunately, both his parents lived to see his principled stand on salary equity succeed and also see their debts cleared by him in full.

But British officialdom did not take its climb-down gracefully. Jagadish was deliberately loaded with arduous routine tasks so that he would not be able to do any research. But he rose to the challenge and started doing his research with simple equipment sometimes bought with his own money, and worked late into the nights. His field of interest at this time was wireless transmission through electromagnetic waves.

In 1887 Heinrich Hertz of Germany had experimentally verified the existence of electromagnetic waves predicted two decades earlier by the brilliant theoretical physicist James Clerk Maxwell. Hertz showed that these waves-not only travelled at the speed of light but also behaved like visible light, being reflected, refracted etc. His work caught the attention of Bose. He succeeded in reducing the wave length of these radiations to the millimetre level and established that they could be polarised by some natural crystals in the same way as visible light. He also developed a sensitive receiver for these radiations (then called "coherer"). He presented his findings in the form of scientific papers, one of them published by the Royal Society of London. But true to his nature, it never occurred to him to patent his coherer. Nor did the potentiality of the longer wave length version of this radiation for long-distance signalling appeal 'to him. Only the science of it interested "him. His contemporary Marconi on the other hand instantly recognised this fact and bent his efforts to constructing wireless communication equipment. Bose's mentor Lord Raleigh had advised him to periodically visit Europe and study the research work there in order to keep abreast of progress in the field. So with a government grant, earned by his work on radio waves, Bose left for Europe on a study tour. He delivered a lecture on the properties of electromagnetic waves in the Royal Institution of Great Britain in January 1897. He came into stimulating personal contact with some of the greatest scientific minds in Britain like Lord Kelvin, Professor Fitzgerald and others. He also visited famous universities in France and Germany.

Bose returned to India in April 1897 and continued his work. The fact that the coherers that he built ran down in performance after prolonged operation but revived with rest intrigued him. The resemblance to human fatigue and revival was uncanny. After studying the phenomenon he came to the conclusion that both the human muscle and coherer underwent similar cyclic molecular changes during activity, fatigue, rest and renewal. When he presented a paper on this titled "On the general molecular phenomena produced by electricity in living and non-living matter" in Paris in August 1900, it evoked a fierce reaction. Westerners, generally regarded as materialists, contended that living matter was different from non-living matter while a member of the East, considered to be very spiritual-minded asserted that they behaved the same way! The development of Biophysics and Cybernetics, several decades later, was to show that Bose

was on the right track. Despite disagreement with his conclusions, the high level of his work led to several offers of professorship for Bose in England. But he felt that he had a duty to serve his motherland and was never tempted by such offers. He also rejected opportunities to commercialise his work on radio waves.

Bose next became interested in the similarities between plants and animals. To the astonishment of many, he showed that plants too have a kind of nervous system and respond to stimuli such as electric current, heat and chemicals.

Since this subject was new Bose had to design and construct many of the instruments required. Among them were the Resonant Recorder which measured the speed of excitatory impulses (electrical in nature) in plants and the High Magnification Crescograph which measured the growth rate of plants and the Polysynthetic Recorder for measuring the rate of carbon assimilation in plants.

A later version of the Crescograph called the Magnetic Crescograph could magnify the growth rate of plants enormously. With this instrument it became possible to carry out accelerated tests to determine the effects of fertilisers, insecticides etc. on plants. Its usefulness to agricultural scientists needs no elaboration.

Bose published several papers and books on this subject including “Responses in the living and non-living” (1902), “Plant Response as a means of Physiological Investigation” (1906) and “Researches on the Irritability of Plants” (1913). By his work Bose became firmly convinced that plants respond to all physical stimuli in the same way as animals. But he firmly rejected the sentimental idea that plants have feelings similar to human beings since he could find absolutely no proof for it. He was ever ready to follow the trail of scientific evidence wherever it might lead but was not prepared to yield to flights of fancy.

Bose had not lost touch with his original field, electromagnetic waves either. He designed the Galena Receiver, which was very sensitive in receiving radio waves. The heart of this instrument was a pair of contacts made of a special material. Radio waves impinging on these contacts generated an electric current. It was actually the forerunner of semi-conductor devices, but was not so recognised then. Bose also devoted considerable time and energy for spreading the scientific temperament among the common people through popular articles in the Bengali language.

The latter half of Bose’s career coincided with the rise of the freedom movement in India. His strong national feeling inevitably drew him into close contact with Rabindranath Tagore and Sister Nivedita, the British-born disciple of Swami Vivekananda. Tagore and Bose strengthened each other’s efforts. But prominent political leaders advised Bose not to give up his scientific career and plunge into the freedom struggle (as he at one stage wanted to do) since there were then very few really capable Indian scientists who could lay the foundation for the future growth of science in free India.

Bose retired from his academic service in 1915. In 1917 the knighthood was conferred on him and he became Sir Jagadish Chandra Bose. On his birthday in that year, 30 November, Bose established the Bose Research Institute. Several Indian industrialists and philanthropists helped him by their financial contributions. His main aim was to create an institution in which what he called “the borderlands” between different sciences such as

Physics and Botany would be studied and where a grand synthesis of different kinds of knowledge would be attempted. Tagore composed the inaugural song for the institute.

Bose continued to be active long after his formal retirement from service. He was elected a Fellow of the Royal Society in 1920. His several publications in this period included “Life Movements in Plants” and “Physiology of the Ascent of Sap”. He visited Europe several times to acquaint western scientists with his work and in turn, to learn about their work.

An overview of the life and work of Jagadish Chandra Bose brings out several interesting facets of his character. He was a patriot and a cultural nationalist, proud of the ancient heritage of his land. But he also saw clearly that this treasure could not be protected from foreign political and cultural assaults unless we absorb Science and use it to strengthen ourselves. He realised that the worst effect of colonialism was the sapping of the self-respect of Indians and urged Indians to excel in science and thus prove to westerners that Indians were not their inferiors even in this field, which the West considered to be its own turf. His own personal contribution and example to this task were immense.

Jagadish Chandra Bose passed away on 23 November 1937, a few days before completing his eightieth year. But he had performed his mission in life and left behind a legacy, which it is the duty of succeeding generations of Indian scientists to carry forward.

2.

M. Visvesvaraya

Visionary Extraordinary

In the case of many great men society is unable to reap the full benefits of their gifts because their ideas happen to be too far ahead of their times. Leonardo da Vinci's sketches of the helicopter made no sense to his contemporaries but aeronautical engineers of the twentieth century are amazed at how close his sketches came to the real helicopters they were building. When Charles Babbage spoke of his “analytical engine” it sounded hare-brained to his peers. But in concept it was quite close to our modern computers. It is a pity that gifted men are not allowed to choose their time of birth!

One such person ahead of his times was Mokshagundam Visvesvaraya, the Chief Engineer and later Diwan of the princely state of Mysore. Long before our Independence he advocated planned economic development, women's education and population control, when the latter two topics particularly were considered close to heresy! If he had been born five decades later he would have found much greater acceptance for his views and correspondingly his success could also have been greater.

Visvesvaraya was born on 28 August 1860 in the village of Muddenahalli, Kolar district of the princely Mysore state. His father Srinivasa Shastry was an Ayurvedic physician and scholar. Young Visvesvaraya had his early schooling in Chilkballapur town. He lost his father when he was only 15 years old. His maternal uncle took up the responsibility of educating him further and got him admitted to Wesleyan Mission High

School in Bangalore in 1875. His intelligence and sincerity greatly impressed his teachers.

After finishing school Visvesvaraya joined the Central College, Bangalore. It was necessary for him to earn to learn. He became private tutor to the children of Muddiah, a minister in the state government. He had to walk long distances, shuttling between his home, college and the minister's house. No wonder long-distance walking became one of his cherished habits in adulthood (and possibly one of the reasons for his longevity). The rigour of his early life also infused in him a sense of discipline and capacity for organising his activities systematically that stood him in good stead throughout a long career.

The principal of Central College, Charles Waters was greatly impressed by Visvesvaraya. The pupil in turn felt himself powerfully stimulated by the encouragement of this great educationist. The two maintained contact with each other long after Waters left for England. To the end of his days Visvesvaraya cherished two gifts given to him by Waters, a Webster's dictionary and his gold cuff-links.

Visvesvaraya completed his B.A. in 1881. Waters helped him to secure a scholarship to study further in the College of Science in Poona (now Pune). He took up engineering studies there. Engineering was not a hot course of study then as it is now. Law and government employment were the prime aims of able young men. The fact that Visvesvaraya nevertheless chose it shows he had a mind of his own and was not swayed by peer pressure. Discipline and thoroughness were part of his character throughout life. He looked upon time as the most precious of all resources, never to be squandered. His working days were carefully planned and organised.

Visvesvaraya completed engineering in 1883, being placed first in the Bombay' Presidency. He won the James Berkeley medal for his proficiency in studies.

While in Poona he also came into contact with the prominent leaders of the Freedom Movement, then in its early stages. Mahadev Govind Ranade Gopalakrishna Gokhale and Lokamanya Tilak were the men he admired. But Visvesvaraya was to devote his life to strength-ening the economic and educational base of his nation. There can be no doubt that it was the right choice for him, given his talents. Even freedom has no meaning unless it brings prosperity and the light of knowledge to the people.

Visvesvaraya's first posting was in March 1884, as Assistant Engineer in the Public Works Department of the Government of Bombay. It took him to Nasik. He was to serve in this department till 1908. He became a specialist in the design and construction of underground drainage systems, water supply systems and darn construction.

His first major innovation was the automatic sluice gates. The dam storing water for the supply of Poona city was not sufficiently high. But it was too weak to sustain the water pressure if the height was increased. Visvesvaraya designed metal gates which supported additional storage of water, but automatically opened and let out the water if it rose above a predetermined level. It was an ingenious and cost-effective solution. It won him a patent from the government but he refused to accept the monetary rewards since he felt that he was only doing his duty as a government servant.

Irrigation has been a vexed subject in our country and has frequently led to violent clashes between groups and prolonged expensive litigation. There was no way everyone

could be satisfied. The only solution was an equitable distribution, by which farmers shared the benefits and also the burdens. In the region of Maharashtra that he worked in, Visvesvaraya formulated the Block System of Irrigation. In this scheme, the region *was* divided into blocks of villages. One-third of the cultivated area of the block was allowed to grow crops such as sugar cane requiring large amounts of water. The other two-third could be devoted to ragi and other dry crops and vegetables. This way all the regions could get a reasonable amount of water through the canal system controlled by the Public Works Department. Even farmers hostile to the idea ultimately discovered that it was beneficial for the soil, in the long run to rotate crops between wet and dry types. An added bonus was greater peace in the area! The government of Bombay was delighted with this outcome and showered high praise on Visvesvaraya. This system is now being widely practised in India. In 1906 Visvesvaraya was deputed to Aden to solve its water problem. Aden was an important military base for the British but was a desert area. Water had to be distilled from sea water or brought over long distances by mule packs. Visvesvaraya solved the problem by 'harnessing the scanty rain water around Aden efficiently and then pumping it to Aden City. He also advocated a closed drainage system for the city. When this was carried out there occurred a dramatic 'decrease in the death rate of the civil population. The correlation between hygiene and health could not have been better demonstrated. Visvesvaraya's ability brought him a series of promotions in a short time superseding many who were his seniors in age and service. This naturally created heart-burn in the affected group. Also he came to realise that the ultimate post, that of Chief Engineer was out of his reach, not for lack of ability but because customarily only Britishers were appointed to it.

These considerations led Visvesvaraya to seek early retirement from the P.W.D. at the age of 47, in May 1908. The Bombay government was reluctant to let him go but finally agreed and provided him with a full pension in spite of early retirement.

His long stay in Poona had widened Visvesvaraya's horizon greatly. Frequent contacts, with nationalist leaders had made him aware of the broader problems of India. Poverty, illiteracy and irrational beliefs were sapping the vitality of the population. Only economic progress, mass education and feminine empowerment could solve these problems. Keen engineer though he was, he came to realise that he should widen his field of activities if his efforts were to yield the maximum benefits for the country. Hence, after his retirement from the P.W.D. his activities gradually expanded to include public policy making and administration.

Immediately after retirement he undertook a tour of Europe. The main purpose was not holidaying or sight seeing. It was to acquaint himself first hand with the important civil projects and industries in general. While in Milan, Italy, he received an urgent message from the government of Hyderabad State, requesting him to take up a short-term assignment to draw up plans to protect Hyderabad city from floods caused by the river Moosi and also for designing a complete drainage system for the city. He replied that he could do it only after completing his tour and also only if- he were paid as much as an Englishman for that job (this was insisted more out of self-respect than for money). Both conditions were promptly agreed to.

Visvesvaraya became Chief Engineer of Hyderabad State in April 1909. After thoroughly studying the problem he suggested several measures including the

construction of a dam across the Moosi River 130 kilometres above the city and another dam across its tributary at a spot much closer to the city. These measures were adopted after some hesitation and solved the problem. So was his scheme for drainage also.

In the meanwhile Mysore State was eager to secure the services of its now famous son. After obtaining assurances about being given a free hand to implement his ideas, he became the Chief Engineer of Mysore State in November 1909. He also held responsible positions in two other fields in the state, technical education and industrial development, besides Railways which also came under his purview: For the next three years he threw himself heart and soul into developing his native state. The famous Krishnaraja Sagar dam was constructed due to his efforts. The irrigation and power provided by it led to higher agricultural and industrial production.

Education commanded a high priority in Visvesvaraya's scheme of things. He fervently believed that improving the quality of the people was the only-sure foundation of a nation's strength. Except for the name he was implementing nine decades back what we now call Human Resource Development (HRD)! One can only marvel at the foresight of the man. Under his tutelage school and college education expanded rapidly. His insight also showed him that women's education held out even greater benefits for society than men's. Conservative people gaped in astonishment as girls trooped to the schools and colleges he specially set up for them. And long before the word "reservation" gained currency he instituted scholarships for backward classes. Compulsory education for all was enshrined as a guiding principle by him in the state, again much before it became an accepted proposition in the rest of India. Among the princely states, Mysore gained the reputation of being one of the most progressive and ahead of even British-ruled provinces in several respects, not a little, due to the vision and energy of its best-known son, Visvesvaraya.

Being an engineer, concern for professional education came naturally to him. Agricultural and technical schools were set up in many centres. With so much of educational activity in the state he felt it an anachronism for them being controlled by Madras University. Due to his perseverance, Mysore became the first princely state to acquire a university of its own.

When the incumbent Dewan of Mysore retired in 1912, the mantle fell on Visvesvaraya. Industrialisation of the state now commanded his attention. The famous Bhadravati Iron and Steel was one of the many industries started by him (now the factory is appropriately renamed Visvesvaraya Iron and Steel Works). Silk and sandalwood industries, for which Karnataka is famous in our present times, were also developed during his tenure. He drew up perspective Five Year Plans for the State's development and hence must be considered the father of this concept in India.

But any rapid change produces resistance from conservatives and from those adversely affected by the change. Visvesvaraya's ambitious and energetic drive not unexpectedly evoked such responses. Gradually it grew stronger and Visvesvaraya felt he could no longer function effectively. Hence he retired from the Dewanship in December 1918.

In the subsequent years he was essentially a free man, able to devote himself to whatever project interested him. Then in 1923 came a call that he could not refuse. The Bhadravati Works, his brainchild, was in serious trouble. Foreign experts advocated its closure for a lengthy period. The Maharaja in desperation turned to the one Indian who

could set things right—Visvesvaraya. For the next six and a half years he bent all his energies to reviving the plant. Despite many dire predictions he did it successfully and handed it over in good condition in September 1929. He did not personally accept the large sum that was due as his remuneration for these years of effort. He requested the government to use it to start an occupational institute. For him accepting the money would have been equivalent to a mother accepting money for nursing her sick child back to health.

On the request of the sovereign Visvesvaraya supervised the Cauvery Reservoir Scheme and the New Bangalore Water Supply Scheme. His efforts to bring an automobile industry into the state were frustrated but he succeeded in getting an aircraft factory established in Bangalore. This was the kernel for the huge Hindustan Aeronautical Limited, which dominates the aircraft industry in India today. He was much in demand as a consultant for water and drainage works in other states.

Visvesvaraya retained his interest in education to the end, particularly women's education. He urged them to postpone marriage at least until the age of 18 and was in favour of family planning (revolutionary suggestions for those days!). He took time and effort to put down his ideas on economic planning. Among the books he wrote on the subject was "Planned Economy for India" (1934).

While being deeply attached to the land and culture of his native country he was very much pained by its shortcomings too. In particular, the Indian habit of fatalistically accepting suffering instead of working to overcome it irritated him greatly. He believed that effort and discipline could overcome most of the problems of life. He himself was a model for what he preached. He once declared that his deepest wish in life was to keep working till his last breath. He was the ideal public servant, a government or people could ask for. He expected his subordinates to work hard but of all he worked the hardest. He was completely out of sympathy with Gandhian economics. "Industrialise or perish" was his motto. He believed that only science and technology could solve our massive problems of poverty and superstitions. It is noteworthy that Free India has chosen this route, however much it might respect Gandhiji.

Awards came to him in profusion, though he never worked for them. The highest of all was the Bharat Ratna conferred on him in 1955. The centenary of his birth was celebrated enthusiastically. After a long and fruitful life, Visvesvaraya passed away on 12 April 1962.

It was India's misfortune that Visvesvaraya's most fruitful years were spent well before Independence. But even with this handicap, he contributed mightily to his country's development. The affection and regard in which he is held long after his death is a tribute to his greatness.

3.

Acharya P.C. Ray

Trail Blazer for the Indian Chemical Industry

Few eminent scientists have become good businessmen or industrialists. It is usually the others who benefit from their discoveries. A notable exception to this rule among Indian scientists was Prafulla Chandra Ray. He was a good research worker and great teacher, affectionately called Acharya Ray by his admiring students. But unlike most scientists he felt it was his duty also to see to it that the benefits of science reached the common man. The Bengal Chemical and Pharmaceutical Works, today one of the major chemical companies in India, was founded by him in 1901. It was not all. He went on to establish pottery works, soap works and canning plants. Further more, this extraordinary man achieved all this in the early years of the twentieth century when India was firmly in the grip of the British as a colony. Needless to say, our colonial overlords had little interest in seeing us progress. That he achieved so much in those times is a measure of the man.

Ray was born on 2 August 1861 as the third of the seven children of Harishchandra Ray in Raruli in the Khulna district of the present day Bangladesh. Though rural based, his father had a keen interest in education and got Prafulla Chandra educated in Calcutta in a well known school.

Bengal was then in a ferment. Western education had awakened many to the deficiencies of our society but also made them aware of the positive aspects of our heritage. The result was a twin drive to reform Indian society and also work for its political freedom. The Brahmo Samaj was one of the most prominent of these movements and Ray felt attracted to it. Throughout his life an interest for modern science was inextricably mingled in him with a strong cultural nationalism reflected in his manner of dress, his interest in our history etc.

After schooling, Ray was educated in the Metropolitan College and Presidency College, obtaining his F.A. degree. He then left for England for further studies under the Gilchrist Scholarship. He obtained his B.Sc. and D. Sc. degrees from the Edinburgh University in 1885 and 1887, respectively. He then held the Hope Prize Scholarship during 1887-88. He then returned to India and joined the Presidency College of Calcutta in 1889.

The India that Ray found on his return deeply disturbed him. The country hardly had any industries. The colonial power was only interested in extracting the raw materials from the country and dumping the finished products back here at a fancy price for what was called "Value Addition". Ray realised that this could be countered only by starting industries in India, even in the face of the indifference and obstruction of the British.

While being quite willing to absorb knowledge of modern science from foreigners, Ray was not ready to concede any superiority to them in other matters. In dress, culture etc. he staunchly stuck to his roots (in this respect we have a lot to learn from the Japanese who eagerly adopted Western science and technology but rejected practically every thing else western).

Ray became well known as a very good teacher and an example to his students, among whom were two future stalwarts, Meghnad Saha and Satyendra Nath Bose. But Ray was also determined to start industries to benefit his country. He founded the Bengal Chemical and Pharmaceutical Works in 1901. But the path was not easy. His attempts to produce citric acid from lemon failed. So did his efforts to produce sulphuric acid "the mother of chemical industries". Finally he succeeded in the production of caustic soda

from cattle bones. The experiments he conducted with this raw material were hardly appreciated by his sorely tried neighbours nor by the police who required to be convinced that they were not human bones!

Ray's company steadily prospered thereafter and more importantly served to stimulate many other Indians to start industries. Today Bengal Chemicals is a leading firm in its field in the country. Ray also founded pottery, soap and canning factories.

Ray's research work also encompassed a wide field. Initially he took up the problem posed by adulteration of food (even in those days!). He next took up the search for the missing elements in the Periodic Tables as known then. He discovered mercurous nitrate, a compound believed to be unstable, in a very stable form in certain yellow crystalline deposits. So fascinated did he become by this chemical that he spent the next several years studying this salt and its derivatives. He also devoted his efforts to the study of ammonium-nitrate, alkyl ammonium nitrate and other compounds. He was to publish more than a hundred papers on his research work.

But Ray still had energy to spare! He was an ardent scholar and was determined to bring out the scientific achievements of ancient Indians, possibly to evoke the pride of his countrymen in their heritage. He wrote "The History of Hindu Chemistry" in two volumes, the first being published in 1902 and the second in 1908. His autobiography also appeared in two volumes, in 1932 and 1935.

Ray was a mixture of tradition and modernity. His dress was Indian and he had a deep pride in our heritage. But he also fought against untouchability and advocated widow remarriage (a horror to most in those days!). Though a nationalist, he believed it was more important for him to lay the foundations of industry in the country than to take an active part in the freedom struggle. He was ever ready to plunge into famine and flood relief works. He was a strong advocate of small and cottage industries. In this however, he was at odds with one of his star pupils, Meghnad Saha. Nor has the course of free India's development conformed to his ideas in this respect.

Ray's popularity with his students was legendary. Even today we refer to him by the title his affectionate pupils bestowed on him "Acharya". His life style was austere, almost comparable with Gandhiji's. He never married and lived with his friends or students. He freely gave away his savings to worthy causes.

Ray served the last twenty years of his official life (1916-1936) as Palit Professor of Chemistry in the College of Science, Calcutta University. He was showered with honours by several universities. He was knighted in 1919.

By the time of his death on 16 June 1944 Prafulla Chandra Ray had seen his country and countrymen advance far beyond what he had known in his youth. Some of his dreams were fulfilled but the biggest of all, the country's freedom, he was not destined to see. But he had trained and inspired a whole generation of chemists who were to carry on his work in free India. They never forgot their debt to him and always referred to him as the "Father of Indian Chemistry".

4.

Srinivasa Ramanujan

A Nearly Lost Genius

One of the obstacles a person of great genius faces is that those around him are unable to understand his work and are left wondering whether they are dealing with some one far above their level, or just an impostor clever at confusing them with high-sounding talk. This is especially so-if the person is of humble birth with no easy access to high intellectual circles. A classic example of this syndrome was Srinivasa Ramanujan, the greatest mathematical genius that India has produced in modern times. Not understood by those around him and unable to cope with an educational system too rigid to accommodate his single-track talent, Ramanujan came perilously close to being consigned to life-long obscurity. Finally this rough diamond had to be recognised by a foreigner and given the polish that Ramanujan's all-too-brief life allowed. If this benefactor too had been as indifferent as the many that Ramanujan approached, our nation might have totally missed this prodigy. His travails should make us ponder over the limitations of our educational system and the remedies required.

Ramanujan was born in Erode in Tamil Nadu on 22 December 1887- His father Srinivasan was a low-paid clerk in a cloth shop. The family was close to the poverty line, with even the necessities of life often hard to-come by. His mother, Komalathammal was-a strong-willed woman determined to see her son come up in life. From her Ramanujan imbibed the deep spirituality that characterised his adult life.

Even as a child Ramanujan was marked out by eccentricities. Highly self-willed and self-absorbed he had the disconcerting tendency to ask his teachers and elders awkward questions about the origins of mankind and other subjects beyond his age. He had his early schooling in Kumbakonam Town High School.

Ramanujan's mathematical talent began manifesting itself when he was about ten years old. He found that he could effortlessly learn the subject by himself and clear the doubts of even boys belonging to senior classes. By the time he was fourteen he was already incomprehensible, as far as mathematics was concerned, to everybody in the school, students and teachers! But he did quite well in the other subjects too and was a prized pupil of the school. He was always cheerful and friendly.

In 1904, Ramanujan finished schooling and entered the Govern-ment College, Kumbakonam. Shortly before leaving school he had come by a copy of "A Synopsis of Elementary Results in Pure and Applied Mathematics" by G.S. Carr. This book had a profound effect on his personality. Until then Mathematics was no doubt his first love but there was room for other subjects, too. But now it became an all-consuming obsession. He could think of no other subject seriously and lectures on history or English simply sailed past his ears while he was intently manipulating his equations! Not surprisingly he failed in his F.A. Examination and lost his scholarship, won on the basis of his school performance.

Ramanujan was sent to Madras the next year (1906) by his parents to try his luck at the well-known Pachaiyappa's College. Here at first things seemed to go his way. The Professor of Mathematics there, P. Singaravelu Mudaliar was highly impressed by Ramanujan's math-ematical gifts and the two used to tackle the problems appearing in

mathematical journals. But the educational system was not willing to bend here too even for a genius acknowledged by his teachers. He did poorly in all subjects other than mathematics and particularly so in physiology, a subject he positively loathed. He took the examinations once more next year and again failed. He then returned to his home in Kumbakonam.

The next few years were really miserable for Ramanujan. He tried his hand at giving private tuitions to students. But he could not make a success of it, even when teaching mathematics. He had the tendency to jump several steps ahead and lapse into higher reaches of the subject not required by the students. They found him utterly incomprehensible, though they respected him for his obvious genius. This was Ramanujan's problem for most of his short life. His level was so high and original that it was beyond the understanding of even most mathematicians. They were always wondering whether he was a genius or just a clever poser!

. But all his troubles faded into oblivion once Ramanujan took up a note book and started setting down his mathematical insights. The famous "Note books of Ramanujan" had their origin in this period. He had a particular fascination for numbers. "Every rational number was his friend", it was said of him. Their inner relationships, closed to other mortals revealed themselves to him as if through a magic eye. He intuitively formulated theorem after theorem on them.

Ramanujan's approach in mathematical research was unorthodox and later was to exasperate other mathematicians no end. Due to his poor educational training he did not realise the need for rigorous proof, which was the forte of Western mathematics. His genius was an intuitive genius. He would arrive at the final solution with a prodigious mental leap but would not care to set down the steps to the solution. Two generations of mathematicians have pored over his note books, trying to prove his formulations. Even now they have not been fully worked out.

Ramanujan was by now over twenty, and in the eyes of his elders 'shiftless and lost in a world of his own'. His mother resolved to infuse "responsibility" into him by the classic Indian method - she decided to get him married! Since implicit obedience to elders was then the rule, Ramanujan married Janaki, eleven year his junior on 14 July 1909. Except for the honour of being later regarded as the wife of a renowned genius the young bride was destined to derive little from the marriage.

Now that he was a "Grihasta", Ramanujan started a desperate search for a job to support himself. In Madras he stayed with friends while he endlessly knocked at doors for employment. Through one of them he approached Ramachandra Rao, the district collector of Nellore, whose amateur interest in mathematics had made him the secretary of the Indian Mathematical Society. Though he could understand-only a little of Ramanujan's work Ramachandra Rao was impressed by his earnestness and enthusiasm and agreed to keep paying him twenty five rupees a month until he could establish himself. It was not much but it at least freed Ramanujan from worrying about his next meal.

Ramanujan spent the next three years, 1909-1912, doggedly trying to get someone to understand him and provide an entry into the world of mathematics. The search for a job also went on simultaneously but less enthusiastically.

Ramanujan published his first mathematical paper in 1911 in the Journal of the Indian Mathematical Society. His habit of jumping steps and lack of clarity made the paper a headache for the editor and had to be revised repeatedly before being published. It dealt with nested radicals that is square root of square root of...¹ He contributed many more interesting problems to the journal and also prepared a second paper. But he was still basically unemployed and this sapped his spirit.

In February 1912, Ramanujan applied for a clerk's post in the Madras Port Trust. At last, he was fortunate to get this meagrely paid but most welcome post in this organisation. Ramanujan joined duty in March 1912. Here he came into contact with two remarkable men who were to play a crucial role in finally bringing him to the attention of the mathematical world. One was Sir Francis Spring, the Chief Engineer of the Port Trust and Narayana Iyer his chief accountant.

Narayana Iyer had a natural interest in mathematics and was the treasurer of the Mathematical Society. It was inevitable that Ramanujan would get close to him and through him come to the attention of Sir Francis. Besides providing him the necessities of life, the job was also light and left Ramanujan free to indulge in his obsession. Any scrap of paper that he came across in the office was promptly covered over with equations and on one occasion ended up on the table of the chief engineer, mixed with other papers! But both Sir Francis and Narayana Iyer were indulgent to this friendly young man with a magnificent obsession. They also brought him into contact with the mathematics professors of Madras colleges, who as many before them found him incomprehensible. Then came the suggestion that he should write to leading mathematicians in Britain to get his ability recognised. The first two that he tried turned him down politely. Then on 16 January 1913, Ramanujan wrote to a professor of mathematics named G.H. Hardy in the famed Cambridge University.

Hardy had enjoyed all that Ramanujan's circumstances had denied him. Son of a school teacher, his mathematical gifts had been recognised early. He was educated in two of the best schools of England, Cranleigh and Winchester and later in Trinity College, Cambridge University, where he won the coveted Tripos. He had then joined the faculty of the Trinity College and was recognised as a renowned mathematician at the young age of thirty-five. Remarkably for an Englishman of that era Hardy was free of prejudices towards coloured people. Fate could not have guided Ramanujan to write to a better person than him.

"Dear Sir, I beg to introduce myself to you as a clerk in ..." began the letter simply enough. But it soon wandered into claims of mathematical discoveries backed by page after page of equations, written in the typical Ramanujan style, jumping steps and careless about proofs. Fortunately he had taken extra care to make his handwriting very clear! Otherwise the background of the writer might have tempted Prof. Hardy to throw the whole thing into the dust bin.

One can sympathise with Hardy for his dilemma when he received this letter. "I had never seen anything in the least like them before" he wrote later. The writer was obviously not a systematically trained mathematician. Hardy at first threw it aside and attended to his work. But the letter kept protruding into his consciousness. Hardy's intuition kept telling him that there was an extraordinary mind behind it. After dinner, Hardy called over his colleague, J.E. Littlewood, an equally brilliant mathematician and

they started working through Ramanujan's formulations systematically. The deeper they delved the more it dazzled them, in spite of the erratic presentation of the matter. By midnight realisation dawned on the two men that they were dealing with a mathematical mind of the highest order—untrained and messy in its ways, but undoubtedly a great mind.

Hardy wrote back to Ramanujan, praising his work unstintingly but also admonishing him to provide rigorous proofs for his leaps of intuition. Needless to say, it had an electric effect on Ramanujan. It was the first recognition of his work from a mathematician of world-class. No longer could those around Ramanujan doubt his genius, even if they understood him no better than before!

A continuous correspondence grew between Hardy and Ramanujan, in the course of which Hardy invited him to come over to England. But crossing the seas was anathema to orthodox Hindus (today it is the fondest wish of many to go to Europe or the USA!). But gradually the opportunities that it provided appealed to Ramanujan and those close to him. Finally his mother clinched the issue by stating that their family Deity had commanded her in a dream to let him go. Perhaps the only unhappy soul in his circle was his young wife Janaki, glad to see her husband recognised but also sad to be left behind. There followed a comic interlude during which Ramanujan had to be coached to cut vegetables with knife and fork, to tie the knot on his tie etc.! Finally, with a fond farewell from his relatives and the friends who had stood by him in dark days, particularly Narayana Iyer, Ramanujan left for England from Madras harbour by the ship NEVASA on 17 March 1914. The rocket had finally cleared its launching pad and was ready to soar off into space,

In Cambridge Hardy spared no efforts to make Ramanujan's life as comfortable as possible. Professionally Ramanujan had at last got into his elements. He was dealing with men who were on his intellectual plane and appreciated and helped him in his work. He went joyously to work- A stream of papers poured out due to the joint efforts of Ramanujan, Hardy and Littlewood. The years 1914-1916 were the 'most productive years of his brief life. They were also probably the happiest.

But as time wore on, two other factors began to affect Ramanujan seriously. Apart from his work, Ramanujan was comfortable with nothing in England. The climate, the food, the strangeness of its customs, lack of social intercourse with people of his culture etc. gradually began to sap his spirit and finally his health too. Nor could he spend a few months in India to spiritually recharge himself. The First World War had broken out in August 1914. Regular passenger service to India by ship was out of the question. Even mail took an inordinately long time to travel. Often Cambridge University resembled as army base, with the wounded streaming in from France and reinforcements passing through to the warfront. Many of the students and some of the faculty, including Littlewood, were drafted for military service.

In 1917 Ramanujan fell seriously ill. But whatever the travails of his body, mathematics continued to reign supreme in his mind and intellect. When Hardy visited him in hospital and mentioned that he had come in a taxi with an uninteresting number 1729. Ramanujan immediately countered "No Hardy, it is a very interesting number; it is the smallest number expressible as the sum of two cubes in two different ways".

In May 1918 Ramanujan was elected Fellow of the Royal Society, the top honour for a man of science. It counted among its past members Sir Isaac Newton, Michael Faraday and James Clerk Maxwell. The news created a joyous sensation in India. One of their countrymen had reached the highest pinnacle of achievement in this field and proved himself the intellectual equal of Europeans. It was a tonic for the battered self-esteem of a people oppressed by more than a century of foreign occupation and domination.

At last the First World War ended on 11 November 1918. Normal life gradually resumed. On 13 March 1919 Ramanujan boarded the steamer NAGOYA for India, arriving in Bombay two weeks later. After a few days he left for Madras.

In the five years that Ramanujan had been away both he and his country had changed much. The freedom movement was now gathering momentum and an awakening of the national spirit was palpable. When Ramanujan left India, he was unknown, but now he was famous, a source of pride to his countrymen. But sadly, there were other changes too. The fat and cheerful Ramanujan of earlier years had metamorphosed into a thin and sickly being, morose, irritable and frequently lapsing into temper tantrums. His former patron Ramachandra Rao, who saw him on his arrival in Madras later remarked that he could foresee the end the moment he saw him.

Ramanujan spent the first three months after his return in Madras. Now he came into close contact with his wife Janaki for the first time. Later he was shifted to Kodurnudi in the deep south of India. It was hoped that familiar surroundings, friends, relatives and the food he was accustomed to would restore him to health. But it was not to be. His illness became progressively worse not withstanding the high quality medical attention that was now available to him.

But the central passion of his life, mathematics, retained its hold on him to the end. Whatever his problems, he was instantly transported to a different world when he sat down to work. He worked on what he called “mock theta functions”. Several experts consider his work in the last year of his short life the most original. He kept up a regular correspondence with the man who had discovered him for the world. Prof. Hardy.

But the march of illness was inexorable and overwhelmed the great mind. Ramanujan’s brief life came to an end on 26 April 1920. He had lived just a few months past his thirty-second year.

An overview of Ramanujan’s life naturally raises several questions. What would have happened to Ramanujan if Prof. Hardy had not recognised his genius? In all probability he would have been lost in obscurity. The loss would have been India’s too. Why was his talent not recognised earlier? Why was he not allowed to pursue his interests? Why was it necessary to insist that he attain a pass level in subjects like English composition and Physiology, for which he had not the slightest interest or aptitude?

The answer to all these questions is an over-rigid and formalised system of education. In Ramanujan’s days the educational system was designed to produce efficient clerks for the colonial power, not great scientists or engineers. But now that we are free, it is essential for us to evolve an educational system that would not miss such gems in the future. Single-track individuals like Ramanujan have to be identified early and an avenue suited to them provided for. If our educational system can not display the imagination

and flexibility required for this, Ramanujan would not be the last gifted Indian to spend the better part of his life in obscurity and frustration.

5.

C.V. Raman

Very Little Spent But Nobel Prize Won

The only Indian scientist to have won the Nobel Prize for scientific work done in India, that too, with equipment worth about Rs. 200 is none other than the renowned Sir C.V. Raman. Prof. Raman believed strongly that it was possible to do very good scientific work in India in spite of meagre resources, provided one was dedicated and innovative and his own career was the strongest proof for his belief. It can also be an example to the present generation of young scientists, many of whom flock to Western nations with the plea that the facilities there are better for research. No doubt they are, but the culture of scientific research can not grow in India unless the work is done in India. What the present situation demands is more C.V. Ramans!

This remarkable scientist was born on 7 November 1888 in Tiruvanaikkaval near Tiruchirapalli in Tamil Nadu. His father was a school teacher. Raman was the second of their eight children. Raman's father was a well-read man and hence Raman was exposed to books on a variety of subject's right from childhood. He also imbibed from his father a love for music. Later as a scientist he devoted considerable time to the scientific study of musical instruments.

Raman had his schooling in Vishakhapatnam in Andhra, where his father became a college lecturer when Raman was a child. Raman was a brilliant student right from the beginning. He completed Matriculation at the age of 11 (obviously there was no age restriction in those days!) being placed in first class. He joined the Presidency College, Madras in January 1903 and obtained his B.A. in Physics in 1904 securing a gold medal in physics. But the small-sized Raman had a problem in the beginning. He used to be regularly asked by teachers "Do you really belong to this class?". On completing Bachelor of Arts (B.A.) Raman was advised to go to England to study further. But his puny figure did not impress the Civil Surgeon of Madras who felt he would not be able to withstand the rigours of English climate. Later in life, Raman used to declare that he was eternally grateful to that surgeon for making him stay on in India. Raman completed his M.A. in physics in 1907, again being placed first. He published his first scientific paper in 1906 concerning the diffraction of light.

What Raman was forced to do on graduation is an eloquent indication of the state of science in India then. He became a civil servant in the Finance Department! While waiting for his posting he married Lokasundari, thirteen years old, with a marked talent for music. Raman was to enjoy long years of marital bliss thanks to the total dedication of Lokasundari to his welfare.

In June 1907 Raman and his wife moved to Calcutta to take up his post. Though he had to grapple with accounts in his office it can be easily imagined that his heart was not in it. On the way to his office stood the Indian Association for the Cultivation of Science, founded by Mahendralal Sarkar in 1876. It was meant to encourage science in India and contained some rudimentary laboratories. It naturally caught Raman's eye and he joined

the Association. He worked for several hours before and after his office hours, long into the night. Only sheer love for the subject could have made him accept such a punishing schedule.

His superior officers in accounts could hardly be expected to share his enthusiasm for science- To them he was just another civil servant to be shunted from place to place. After stints in Rangoon and Nagpur the relieved Raman was sent back to Calcutta in 1910. The next few years saw him pour out a series of scientific papers of the highest quality. His work began to attract the attention of experts in the field.

In July 1917, Sir Asutosh Mukherjee the Vice' Chancellor of Calcutta University offered Raman the Palit Chair of Physics in the University. The delighted Raman accepted it. At last he could forget about accounts and balance sheets and work exclusively on what he loved dearly!

The period 1917-32 was the most productive period of Raman's career. He was an excellent teacher and research guide. A galaxy of students and research scholars, later to assume notable positions in the annals of India's great scientists, were shaped by him.

Raman made his first visit abroad, to England in 1921 to attend a conference. His sea voyage had momentous consequences for physics. He was fascinated by the brilliant blue colour of the sea. All of us admire the blueness of sea but very few of us would devote ourselves to finding out why it is blue. Raman was one of the few. By simple experiments in the ship he satisfied himself that it was riot simply the reflection of the blue sky. What else could be the cause? He intuitively felt that it was due to some kind of interaction between the water and sunlight. But it needed proof. So stimulated was he by this phenomenon that scattering of light by different mediums became his main subject of research thereafter.

On his return to India Raman took up in earnest this problem. In his experiments light beams were passed through a variety of liquids and the effects studied. Finally in 1928, it was firmly established that when monochromatic (single colour) light is passed through a liquid, the light quanta and the liquid molecules interact and scatter the light.

The emergent light is found to be of a different colour from the original beam. It is shifted to both higher and lower levels of energy, relative to the incident light. This is the famous RAMAN EFFECT.

The discovery had a catalytic effect on further research world-wide. Even today it is a fertile field of activity with the availability of lasers making it a powerful tool. It is widely used to study the structure of different substances, to study the combustion process in internal combustion engines, etc.

His achievement led to Raman being knighted in 1929 and on 10 December 1930 came the highest award a scientist can aspire for, the Nobel Prize. It can be imagined how much it would have stimulated the pride of his countrymen, with their self-esteem sapped by long years of foreign subjugation.

In July 1933 Raman took up the post of the Director of the Indian Institute of Science. He initiated research work there on diffraction of X-rays, ultra-sonics etc., in addition, of course, to his favourite topic, interaction between light and matter, both solid and liquid.

Raman was a keen promoter of science also. A gifted speaker, he lectured widely, stressing the joy of scientific pursuit as well as the need to uplift our society through science. He was a founder member of the Indian National Science Academy. Today the roster of members of the Academy includes practically all the great scientists India has produced.

Like many scientists Raman was not in his element in administration. Many of his decisions were bitterly criticised and finally he gave up, with great relief, the Directorship and went back to what he was cut out to do - scientific research.

Before his retirement Raman built up a research institute of his own, the Raman Research Institute in Bangalore. He continued his work there, gathering around him a group of gifted research workers till his death on 21 November 1970.

Apart from the Nobel Prize, Raman was honoured with the Franklin medal, Hughes medal and many others. His proud country also bestowed on him the highest award of the land, the Bharat Ratna, in 1954.

Throughout his life, Raman was an exponent of what might be called “nationalism in science”. He wanted Indian scientists to work in India with the resources available to them. He wanted them to choose their lines of research independently and not to simply imitate the approach of Westerners. Like other great Indian scientists of his period he never considered settling abroad. It is a source of amazement to us now that even Indians of the highest calibre in science in those days chose to stick to their motherland and do their best here. Surely there is a lesson in this for our youth of today. Relatively few people in our country are fortunate enough to receive a first-class training in science and technology and it is their duty to do their bit for the much more numerous but less fortunate countrymen, whose tax contributions subsidise higher education. It would also be the best way of honouring the memory of the earlier generations of Indians like Raman who set an example by standing by their country under much more trying conditions.

6.

Meghnad Saha

Handicaps No Bar to Great Achievement

As is well known, it has been the fate of many groups of people to suffer persecution and discrimination at the hands of the dominant sections of their own society. Does such treatment prevent them from achieving their full potential? For the average members of the unfortunate group there is no doubt that it does. But exceptionally gifted people can not be kept down by any amount of suppression. Albert Einstein, Sigmund Freud, Booker T. Washington and Jessi Owens were examples of individuals simply too gifted to be kept down by discrimination. Dr Meghnad Saha, one of the most distinguished scientists produced by our country, also proved that genius and perseverance can overcome the crippling constraints imposed by a traditional society on certain caste groups. In spite of his bitter experience, it is a credit to him that he hated the system but never the individuals belonging to the hostile groups.

Meghnad Saha was born on 6 October 1893 in Seoratali, a village in what is now Bangladesh. His father Jagannath Saha ran a small grocery store. The child was born to the accompaniment of raging rain and resounding thunder and hence was named "Meghnad", meaning the roll of thunder. The name also fitted well the later temperament of Saha, aggressive, assertive and uncompromising in fighting for what he believed was right. He was a healthy child and revelled in swimming in the abundant rivers and canals typical of East Bengal.

It was no easy matter for Meghnad to get educated: He belonged to a depressed caste, his parents were poor and his native region did not have a good educational infrastructure. Additionally, his elder brothers had not done well in school and hence the parents were loathe to 'waste' money on educating him. But young Meghnad had two things going for him. He was brilliant and also determined to overcome the handicaps imposed by his birth and realise in full his God-given potential. Education beyond the primary stage was available only in a place ten kilometres away and the transportation system was primitive. Hence he had to live with a kindly sponsor near the school. But even such a kind man was not above the prejudices of his age. Meghnad had to wash his own dishes - no one else would do it. But Meghnad, realising that education alone could help him rise in life, accepted it stoically. He completed the Middle School in 1905, being placed first in Dacca division. He next joined the Collegiate School in Dacca City.

The British Viceroy at this time was Lord Curzon, regarded as the most imperial of the Viceroys and British prestige in India was then at its apogee. But there were also the first stirrings of a freedom movement and Bengal was the intellectual fountainhead of Indian nationalism at this time. Hence, Curzon decided to play the game of "divide and rule" which had so greatly helped the British in winning and ruling their vast empire. He partitioned Bengal into an eastern and western parts. "Administrative convenience" was what he claimed as its reason. But since the two parts neatly formed Hindu and Muslim majority areas the mischief behind the move was patent. Nationalist Bengalis virtually rose up in revolt. Their agitation gradually found an echo in the rest of the nation too.

In spite of his bitter experience of caste prejudice young Saha had developed strong nationalist feelings and took part in the agitation. He was expelled from the school. But fortunately another school accepted him and he completed schooling in 1909.

Saha stood first among the aspirants to college in the entrance examination and joined Dacca College. He completed Intermediate Science in 1911, again brilliantly, and joined the Presidency College in Calcutta.

Saha's contemporaries at Presidency College included many who were to become famous later. One of his juniors was Subhash Chandra Bose, and a classmate was Satyendra Nath Bose. Nor were his teachers any less illustrious, including as they did the likes of J.C. Bose and P.C. Ray. In particular, P.C. Ray left a deep impression on Saha. Ray attached an even greater value to patriotism than devotion to his profession. "Science can wait, Swaraj cannot" was his constant refrain. But even Saha's brilliance could not save him from petty caste-based harassment in Calcutta. Though he hated the practice he never extended it to the individuals of the perpetrating group. He seemed to believe that they were simply conditioned to behave so by the system and hence that is what needed changing. And he did not allow these slights to affect his academic effort. He completed

the B.Sc. course in 1913 and M.Sc. in 1915, being placed second in the Calcutta University.

But social harassment was not the only problem that Saha faced in Calcutta. Money too was a constant source of worry. He had to take private tuitions and also support from his mother and elder brother Jainath who generously wanted his little brother to achieve the academic distinction that he could not.

Saha's nationalist feelings were by no means submerged by his strenuous academic pursuits. He kept in touch with freedom fighters like Bagha Jatin who later sacrificed his life heroically in an encounter with the British police.

On graduation Saha tried to appear for the much-sought after Finance Service Examination. He was not allowed to do so on account of his past nationalist activities - fortunately so, as otherwise Saha might have spent the rest of his life on balancing budgets and interpreting rules! The loss would have been his and the nation's too.

Saha then joined Calcutta University, where he and his life-long friendly rival, Satyendra Nath Bose were posted as lecturers in the Physics Department. Saha's earlier training had been mainly mathematical and it took him some time to master experimental physics. But he came to develop a keen interest in the subject. Practically working on it, however, was not easy. University grants were limited and aimed at producing lower level bureaucrats. Scientific experiments were largely dependent on the private munificence of individuals like Tarakanath Palit and Rash Behari Ghose.

The Theory of Relativity and Quantum Mechanics were developing rapidly in this period and Saha was naturally attracted to them. He personally translated the former from German to English in 1919. He published his first scientific paper titled "On Maxwell's stresses, concerning the electromagnetic theory of radiation" in the Philosophical Magazine in 1917. In the next two years, a stream of papers on light, elasticity, Quantum Theory etc. followed. In recognition of his contribution the Calcutta University awarded him the D.Sc. degree in 1919.

A major turning point occurred in the personal life of Saha when he married Radharani Roy in June 1918. The father of the bride was impressed by Saha's credential, but not the grandmother of the motherless girl. She even taunted the father saying it would be a better idea to drown the girl in the river Padma. Later when Saha became famous, he once jocularly asked the old lady whether she still retained the same opinion. But she was not to be fazed so easily. "It is my granddaughter who has brought you all this luck" was her cool reply!

In the course of his research work Saha became intensely interested in the field which now indelibly carries the mark of his contribution-the spectra of stars. Fraunhofer had discovered in 1814 a large number of dark lines in the spectrum of sunlight. In 1859 Kirchhoff proved that these lines represented definite chemical elements which had been heated to the state of luminescence. Through the use of this knowledge the gas Helium was discovered in the sun before it was discovered on earth! But when better spectrometers were developed it was found that there were bright lines (called flash spectra) as well as dark lines and that the number of lines of both classes far exceeded the number of elements known. This set the field in turmoil, until Saha came up with the solution. When a gas is heated some of its electrons are stripped away leaving positively

charged nuclei and negatively charged electrons which are free. This process is called ionisation. Saha developed the equation that now bears his name. He showed that the extent of ionisation depends on the pressure, temperature and the ionisation potential of a gas. Hence the same gas at different pressures and temperatures would produce different spectral lines. Since the sun is hottest at the core and the temperature gradually decreases from the core to the outer envelope the presence of so many spectral lines was explainable. Saha's work brought back order to the subject of Astrophysics and has been rated as one of the most important contributions ever made to the subject.

Experimental verification of the theory was possible only in the advanced Western nations. Hence Saha, with assistance from some Indian foundations, set sail for England. But there Prof. Fowler, with whom Saha wanted to work, advised him that Prof. Nernst in Germany was a better person to work with on this problem. The First World War had ended only about two years back and there were still considerable bitter feelings between Britain and Germany. Yet a British scientist was telling Saha that a German professor was for him the best man to work with! There can not be a more gratifying example of the spirit of science triumphing over narrow nationalism.

Saha joined Prof. Nernst's laboratory in February 1921. With his knowledge of German he easily got into a working relationship with Nernst and his colleagues. He also could meet several eminent German scientists like Einstein and Planck. His work commanded respect and proved his firm belief that if one concentrated on one's work reward and recognition would follow on their own.

While in Germany Saha received a call from Asutosh Mukherjee to come over and take the post of "Khair Professor" of Physics in Calcutta University. Saha returned to India and took it up in November 1921 but found that financial constraints prevented the University from supporting his research fully. Hence he took up another offer from Allahabad University in 1923. However, this University too was dependent for funds mainly on the government and British rulers were least interested in Indians -making progress in science. But Saha put to work his priceless ability as a teacher. Several of those he taught eagerly took up research work under his guidance and made up for lack of resources by their enthusiasm and hard work. Many of them later rose to eminent heights in their profession. During this period Saha also wrote a classic textbook, "Text Book of Heat".

Saha was elected a Fellow of the Royal Society in 1927. The next decade was possibly the most fruitful in his career. He also became involved with nuclear physics and (Paul) Dirac-Saha formula for calculating the pole strength of magnetic monopoles is a permanent reminder of his success in this field.

Saha's outlook was gradually broadening during this period. The poverty, illiteracy and ignorance afflicting the Indian people pained and angered him simultaneously. Perhaps remembering P.C. Ray's words he decided that it was at least as important to work for the welfare of Indians as for the advancement of science. He believed that vigorous application of science was the answer to India's problems and hence the spreading of scientific temper among the people, a matter of high priority. He founded the U.P. Academy of Sciences in 1930 for this purpose and was its first president. It was also an aim of the Academy to make Indian scientists get out of their "Ivory Tower attitude and involve themselves in the technical problems of the nation.

In the year 1936 Meghnad Saha left on an extensive tour of Europe and USA to study the research work there. Nuclear Science was in great ferment at this time. Scientists whose names were to become famous like Enrico Fermi, Werner Heisenberg, Niels Bohr and many others were laying the foundations of this new discipline. Their work was to pave the way for the mushroom clouds over Hiroshima and Nagasaki. But Saha believed that the peaceful uses of nuclear energy would also be great. To the end of his life he had great trust in the benefits that nuclear energy could provide humanity.

Saha became increasingly disillusioned by the working atmosphere in Allahabad University. When he felt that he had no chance of rectifying it he readily accepted an opportunity to get back to Calcutta University in July 1938.

To promote research in nuclear physics Saha managed to secure in 1940 a grant of Rs. 60,000 (a large sum in those days!) from the Tatas, with the help of Pandit Nehru for constructing a cyclotron. But the Second World War was raging and its construction had to be postponed. It was also becoming clear that the days of the British Raj were drawing to close. Hence Saha turned his attention to Indian leaders like Pandit Nehru, who were keen enthusiasts of science. As a result, work on the Institute of Nuclear Physics began in 1948, hardly a few months after Independence and was completed in January 1950 (today it has been fittingly renamed as Saha Institute of Nuclear Physics). It has attracted brilliant students from all over India. Saha was also made the Director of the Indian Association for the cultivation of Science (where Prof. C.V. Raman did his Nobel Prize winning work}. Saha now entered a phase of life marked by activism for the cause he believed in. He got elected as an independent from the Calcutta North-West Constituency in the first general elections of 1952. His politics had a definite leftist orientation. His experience of obscurantism had turned him into a fervent rationalist, scornful of many of Indian superstitions. He had a good knowledge of our scriptures and could counter traditionalists by quoting chapter and verse from them! But he was also a fervent patriot who admired the heroes of the Rajput and Maratha periods. He believed that it was the duty of Indian scientists to help solve the country's problems.

Saha was also scornful of "Cottage Industry Economics". He felt that it would make the country so weak as to invite foreign occupation or domination. Once when a guest in his house, who subscribed to this type of economics, wanted to go to the railway station urgently, Saha mischievously asked him if he should order a bullock cart!

Like many intellectuals of that period, Saha believed that planned economy was the salvation to our economic problems. The bitter experience of colonial exploitation had led many intellectuals to hate capitalism (what we today call a liberal economy) and believe that socialism of some form was best suited to us. But humans are not blessed with the power to foresee all the consequences of their beliefs. In this matter as well as on the question of nuclear power generation general opinion has today shifted from what Saha believed in. But there can be no doubt that Saha sincerely believed that what he advocated was good for the country.

Saha had witnessed personally the ravages of floods in his native Bengal. The already poor people of the region were driven to the very edge of extinction during such times. Hence he became a strong advocate of river valley schemes to control floods, similar to the famed Tennessee Valley Authority (TVA) in the USA. At least partly due to his

constant urging the Damodar Valley Corporation (DVA) was formed and a series of dams built to control floods.

Saha was considerably perturbed by the irrational proliferation of calendars in the different regions of India (more than thirty of them exist!). Originally meant to fix holy dates they had deviated wildly from the actual physical seasons of the year after centuries of use. A Calendar Reform Committee was formed in 1952 with Saha as Chairman. After an exhaustive study the committee recommended that the SAKA era be used as the unified calendar for the country, starting from the day next to the vernal equinox day. It would also have leap years. But sentiment is often stronger than rationality and Saha's efforts were only partly successful.

As a Bengali and a sensitive person Saha was deeply affected by the flood of refugees pouring in from East Bengal (where he had spent his early life) due to the partition. He took up the Chairmanship of the East Bengal Refugees Relief Committee and studied their problems. He recommended several changes in the government's relief programmes. He felt that the best solution to the problem would be to provide creative employment to the refugees. He pointed out how West Germany, with a proportionately larger refugee load had turned the problem into an opportunity by putting the refugees to work, finally achieving what the world came to admire as the "German Economic Miracle".

Saha was a strong believer in the linguistic reorganisation of India. He felt that only by providing for the full development of each Indian language in its region can a country as diverse as India could be held together. In this matter Saha has been proved right. The linguistic formation of Indian states, in spite of occasional frictions, has stood the test of time.

In his final years Saha devoted considerable effort to rejuvenate the Indian Association for the Cultivation of Science. This once famous institution had gradually run down over the years. He got it shifted to a new building and reorganised its working. It again started attracting students from all over India, and distinguished men from abroad like Prof. Linus Pauling:

While on an official visit to Delhi, Saha suddenly collapsed and died due to a massive heart attack on 16 February 1956. His colleagues and the country were shocked by this unexpected and premature end to a great career.

If the life of Prof. Meghnad Saha is viewed in totality, his courage of conviction stands out as prominently as his scientific ability. He never hesitated to stand up for what he believed in, whatever the personal consequences. He condemned the superstitions and inequities of our society. He was totally opposed to the economic theories that advocated village economy and eschewed industrialisation. He was fully aware of the fact that by this he was irritating many of his countrymen. But Saha was nothing if not the personification of courage.

Saha also shines out as a beacon to the depressed sections of our society. By overcoming the obstacles imposed on him by his birth and reaching the pinnacle of eminence he proved that "depressed" people are no less in intelligence or ability to any other group of people. They too have the potential to rise as high in life as anyone else.

Satyendra Nath Bose

A Name Immortalised

It is a common human craving to earn an immortal name by some great achievement. For the vast majority of mankind this is an impossible dream. Their names are swept away by the tide of time. Among the few who achieve it are some political leaders, soldiers, authors and scientists. White soldiers and political leaders may have cities and countries named after them, the scientist is usually remembered by naming after him a physical law (eg. Newton's Laws of Motion) or a physical measure (eg. volts, amperes, watts). One of the very few Indian scientists who have made it into this select group is Satyendra Nath Bose, after whom a subatomic particle has been named "Boson". Satyendra Nath Bose was born in Calcutta on 1 January 1894 into a family which had already two generations of government service behind it. His father Surendra Nath Bose was an accountant in the railways. Hence Satyendra Nath had an in-built advantage when it came to educational opportunities. On top of it he was a gifted child too. His schooling was mainly in the Hindu School, with a rich tradition to its credit. He completed his schooling in 1909. He was marked out by a high talent for mathematics and naturally became a favourite with the teachers.

Bose then joined the Presidency College, Calcutta. His batch contained many students who were later to achieve great distinction in scientific research. But they also lived in a Bengal which was then the citadel of Indian Nationalism. In particular, the partition of Bengal in 1905 stirred Bengali intellectuals in a way no previous event had done. Hence most of the students of Satyendra Nath's time fervently wished for the end of the British rule, though they were also determined to absorb the modern science that the British had introduced in India. They felt instinctively that keeping step with European progress alone would enable Indians to keep the Europeans out! This atmosphere was to make Satyendra Nath a "cultural nationalist". He was to later strongly advocate the study of even science in one's mother tongue.

Satyen passed the Intermediate Examination in 1911 being placed first in the Presidency (Meghnad Saha was second). The pattern was repeated in the B.Sc. and M.Sc. examinations also. He came to be known as the one who never stood second in any university examination! But Satyen was no selfish or self-obsessed student. He spent a considerable amount of his time in helping other students in their studies. He also had a gift for languages. In particular, his felicity in German was to prove a great help in his career.

In 1914, while still a student Bose was married to Ushabati, the daughter of a medical practitioner. He accepted his mother's choice of the bride but insisted on not taking any dowry. But he also insisted that the father-in-law provide for the feeding of his large circle of friends attending the marriage! Throughout his life Satyen made friends easily and spent a lot of time visiting them or conversing with them. This was rather unusual for a top-ranking scientist. But Bose never considered it a waste of time. To him it was a source of intellectual stimulation.

In 1916 Bose was appointed as Lecturer in the University College of Science. His colleague in the Physics Department was his friendly rival Meghnad Saha. Both were

mathematically-oriented young men who, by their own self-study had gained proficiency in physics.

Bose published his first research paper on “The Influence of the Finite Volume of Molecules on the Equation of State” in the *Philosophical Magazine* of London in 1918. His next two papers were purely mathematical in nature.

In collaboration with Saha, Bose translated Albert Einstein’s papers on the Theory of Relativity from the original German into English. It was in fact, the first English translation of these seminal papers. It is rather surprising that it had to be done by two young men from far-away India and not by scientists in England, geographically so close to Germany.

At this time, a new university was being formed in Dacca and its administrators, eager to attract talented faculty members invited Bose to be a Reader there. Bose accepted and moved there in 1921.

Though the facilities at Dacca were not first-class, Bose made up for it with his enthusiasm. Ever the perfectionist, he was dissatisfied with Max Planck’s ways of deriving some of his equations and produced a brilliant paper, “Planck’s Law and Light Quantum Hypothesis” in which he worked out rigorous derivations for them. So impressed was Albert Einstein with Bose’s paper, which he had received for comment, that he personally translated it into German and got it published in the German journal of science *Zeitschrift fuer Physik*. Can any young physicist hope for a greater honour than this?

The collaborative work between Bose and Einstein that ensued ultimately resulted in the well-known Bose-Einstein Statistics used in Quantum Mechanics. Subatomic particles which obey Bose-Einstein statistics came to be known as “bosons” after Bose.

Satyendra Nath Bose undertook a study tour of Europe in October 1924. He spent about a year in France, working in the laboratory of the famed Madame Curie. He spent one more year in Germany. His only German contact hitherto had been with Einstein, but now he could interact with other famous German scientists such as Lise Meitner, Otto Hahn, Wolfgang Pauli and Werner Heisenberg. Berlin was at this time practically the science capital of the world. Hence Bose found his sojourn in Berlin highly interesting and beneficial. He was to put to good use at Dacca the experience he gained there.

Bose returned in Dacca to 1926. In his personal life he was quite lucky. Always surrounded by relatives he was also blessed with plenty of children, seven surviving ones. He felt comfortable in Dacca and remained there till 1945.

Though himself analytically minded Bose tried his-best to build up the experimental facilities at Dacca and encouraged students to use them. This attracted good research workers and the most notable of them was Dr K.S. Krishnan who did his seminal work on magnetic anisotropies there and published a number of papers.

By 1945, Bose was beginning to feel uncomfortable in Dacca. The communal tensions which led to the painful partition of 1947 were developing rapidly. Bose therefore readily accepted an offer of the Khaira Chair Professor in the University of Calcutta. But the period spent at Dacca was, according to his intimates, the happiest period of his career.

The financial grants for research in Universities of those days look ridiculously low for us, even allowing for the lower prices prevailing then. For example Bose and other full professors were allowed Rs. 2,500/- per year! Nevertheless, Calcutta University gained fame as one of the most active and creative research centres in India. Drive and determination were used to compensate for paucity of resources.

India's independence, gained in August 1947, proved both a blessing and a problem for the research community of Calcutta. The riots and mass emigration that accompanied the event upset academic activities. But the installation of governments, both at the state and at the centre, genuinely interested in Indian scientific progress was an immense fillip to scientists. Bose's laboratory became a centre for excellence in X-ray crystallographic studies. He was made the President of the Indian Physical Society for the period 1945-1948. Subsequently he was awarded the Padma Vibhushan in 1954 and in 1958 elected a Fellow of the Royal Society of London. Bose's last significant scientific contribution was towards the evolution of a Unified Field Theory, which tries to combine electromagnetic forces and gravitational forces. But it still continues to elude the scientific community.

In 1956, Satyendra Nath Bose became the Vice Chancellor of Visvabharati, better known as Shanti Niketan, forever associated with the memory of Rabindra Nath Tagore. The ideal of the institution to achieve a synthesis between Science and Spiritualism, between the ancient East and Modern West was naturally attractive to Bose and he did his best to achieve it. With his natural friendliness he also had no difficulty in getting on well with everybody.

But like so many other scientists Bose too discovered that administration was not his cup of tea. His proposals evoked fierce resistance from some sections of the staff and he was temperamentally not capable of resolving such conflicts. With a sense of relief he went back to Calcutta University and his beloved research students in 1959. He continued his association with students as an Emeritus Professor and National Professor until his death on 4 February 1974, shortly after completing his eightieth year.

Satyendra Nath Bose was a complex character, not easily classified. He was gifted with a brilliant mathematical mind but unlike most scientists did not put all his energies into his research work. He had interest in a wide variety of subjects including literature and music. He spent considerable periods of time in conversing with his friends. He was open for anybody to meet and needed no appointments. He was a strong believer in science and its universality. But he was equally convinced about our need to preserve our own languages and culture and not be swamped into becoming imitation westerners. He put considerable effort into popularising science through Bengali. He strongly believed that higher level scientific thinking was possible only in the mother tongue.

Bose earned the respect of men like Einstein by his work when India was a colony and offered little resources for research, it is an achievement and example to be remembered (and followed) by the Indians of today.

Yellapragada Subba Row*His Obsession was Conquest of Diseases*

Great scientists, social workers and political leaders benefit humanity immensely. Immeasurable indeed is the debt that mankind owes these highly dedicated people. But often a heavy price is paid by their close family members who suffer neglect due to the obsessive involvement of the head of the family in his work. A prime example of this type of person was Dr Yellapragada Subba Row, who discovered cures for many dreaded diseases but through his all-consuming passion for his work, brought on himself much suffering and on his close family members too. The only gainer was humanity at large, delivered from the threat of many killer diseases through his efforts.

Subba Row was born on 12 January 1895 in Bhimavaram in the West Godavari district of Andhra Pradesh. He was the third of the seven children of his parents. His father, an official of the Revenue Service had to seek premature retirement on account of poor health. Hence the family was always enmeshed in financial problems. His mother, Venkamma was a strong-willed, domineering woman. It was she who provided Subba Row and his brothers with the motivation to break out of the shackles of want and make their mark on the world. She drove them hard but never spared herself either. Subba Row was to owe much to her sacrifices. He was gratefully aware of it, though he did not find her assertive ways easy to bear either.

Subba Row had his early education in Bhimavaram. Quite early in life, a strong ascetic, self-denying streak surfaced in him, to persist throughout his life. The concepts of renunciation of emotional ties and service to humanity attracted him greatly. He was indifferent to studies and failed in the Matriculation Examination in July 1911. Consequently he was packed off to live with his elder brother Purushotham, a school teacher and freedom fighter, in Rajahmundry. The hope was that the elder brother would be able to bring him round to take his studies seriously. But the move was infructuous since Subba Row again failed in his Matriculation examination. However, he was inspired by the dedication of his brother to the freedom movement and this was to influence his later life.

Subba Row was next sent off to the Hindu High School in Triplicane, Madras. While he was there his father passed away in January 1913. When Subba Row came to attend the subsequent religious ceremonies in his village he came to realise at last how much his mother was sacrificing to get him educated. Bereft now of even the meagre support of her husband she sold off her last jewels to support his studies. Sobered by this fact, Subba Row put in the necessary effort and passed the Matriculation tests. He next underwent the intermediate course in Presidency College.

He now had to decide the course of his career. He chose Medicine. This was a surprise to his family since he had never displayed any interest in this profession. But his motive was something he did not reveal to them. Since “Sanyas” was impossible without his mother’s consent he thought medicine was the next best way to serve mankind!

Subba Row joined the Madras Medical College in 1915 and earnestly plunged into his studies. But medical studies were highly expensive {even in those days} and his family was hard put to support him. The contributions that a few friends made was too meagre to

help in the matter. Finally, against the grain of his nature, he chose a typically Indian solution - to get married and use the resources of the father-in-law!

Subba Row's mother welcomed the decision for a different reason. She hoped it would cure him of his "madness" for religion! Accordingly, on 10 May 1919 Subba Row got married to Seshagiri, twelve years junior to him. For the bride at least the future was to prove harsh. She was destined to enjoy very little time with her husband on account of his consuming passion for work.

Medical education in India, like much else in those days, was dominated by the British. Their nationals held all the key positions. Their long rule of India had infused in them the feeling that they were born to rule over Indians and they were quick to be irritated by any show of defiance, however mild. When Subba Row, thanks to his brother's example, wore white Khader coat to the laboratories one of the British professors sneered "Why can't you wait until Gandhi becomes Viceroy?" The sharp-witted Subba Row was not one to let it pass. "Gandhiji will not care to become Viceroy" was his retort. The result was the vindictive Britisher saw to it that he got the lower L.M.S. Certificate instead of MBBS.

As for a career, private practice never attracted Subba Row. His burning ambition was to discover medicines that would cure diseases that were decimating people. India was too poor for such opportunities and Subba Row disliked British behaviour too much to work in England. The USA was the only other possibility. He applied to the famed Harvard Medical School and in June 1921 secured admission to the post-graduate course in tropical medicine. But it carried no scholarship and hence Subba Row had to search for financial support. He resolved to take the help of his brother Purushotham. But two tragedies in quick succession blew his plans apart. The much-loved Purushotham wasted away and died of tropical sprue. Subba Row was powerless to save him from this grim disease. A few days later the disease claimed the life of his younger brother Krishnamoorthy too. A fierce determination welled up in Subba Row to find a cure for this killer ailment which had dealt his family such deadly blows.

With his plans for studying abroad shattered for the moment, Subba Row joined the Madras Ayurveda College as a faculty member. His life had been saved by Ayurvedic medicines when as a boy he suffered from serious diarrhoea. Hence Subba Row had high respect for the system. But he soon realised that India had no resources to support research in any system of medicine. He once again applied to Harvard and secured admission for the course starting in September 1923. But his financial position was no better than earlier. His frantic efforts secured promise of help but no ready cash from a private charity. With his father-in-law's help he just managed to buy the essential items for his trip with a little money left over to manage the early days in the USA.

Subba Row boarded the steamer "S.S. Kashgar" on 29 September 1923 in Bombay. He had received a fond farewell from his colleagues and friends in Madras. To his wife, not still out of her teens, he earnestly promised to return before three years. It was a promise never to be fulfilled. The young girl was never again to see her husband.

The Britishers in India were not to send off Subba Row uneventfully. A customs officer asked him mockingly why he needed an American degree. "To come back and take away your job" was the prompt retort!

Subba Row took the train from Marseilles and then the ferry to reach London, from where he set sail for the USA. He arrived in New York on 26 October nearly a month after he left India (today's jets would do it in a day!). He arrived the same night in Boston by train.

The problem of paying his fees and supporting himself now confronted Subba Row. Scholarships were rare in those days and part-time jobs were difficult to come by. The white races then lorded it over the earth and coloured people were very much at the receiving end. But even the most hostile or indifferent society always has some good-hearted individuals in its midst. Subba Row's professor Dr. Richard Strong helped him to pay his fees and meet his living expenses in the initial period. Another anonymous donor, later discovered to be young colleague, kept sending small but helpful amounts to him. The only job Subba Row could find was that of cleaning the bedpans in a hospital. Not standing on his dignity as a fully qualified doctor. Subba Row took it up since it brought in some much-needed cash.

Subba Row came to admire much in the American method of doing research. Their approach was very systematic and the researchers very persevering in their quest for cures. The research managers gave them full freedom in their work and none was blamed even if the whole effort ended in failure. But in the long run this approach worked spectacularly. The few successful cures developed more than compensated for the many failures.

Subba Row completed his course and obtained the Diploma in Tropical Medicine in June 1924. The hardship of a year that he had to undergo for this must have faded from his memory in the glow of success.

Subba Row became convinced that only in the USA was it possible for him to do the kind of research that he longed to do. Hence he did not return to India and worked on as a research assistant to Dr. Cyrus Fiske in the same university. The first task assigned to him was the development of a method for the determination of phosphorous concentration in human tissue.

After a strenuous effort Subba Row succeeded. This method became known as the Fiske-Subba Row method. It was described in a research paper in the December 1925 issue of the "Journal of Biological Chemistry". To his great relief, the first instalment of the Indian scholarship was also received at this time and he was taken in as a regular research scholar at Harvard. These two developments eased his financial position greatly. But what gave him the greatest satisfaction was his first success as a researcher. It immensely increased his confidence and also fuelled further ambition.

Subba Row threw himself with great enthusiasm into his next task, the determination of the biochemical changes that take place in the human muscle during exertion and relaxation. He established that the concentration of a chemical that he and his associates called phosphocreatin was an accurate indicator of muscle condition. A resting muscle had a higher concentration than a fatigued muscle. Resting the muscle restored it to the original level. These findings were published in the April 1927 issue of "Science", a magazine of the American Association of the Advancement of Science. He was beginning to command high respect and even awe on account of these successes. It also led to the Rockefeller Foundation offering him a Fellowship. The much higher stipend that it carried finally solved his personal financial problems.

Four long years had elapsed since he left India. The distress and exasperation of his wife and other relatives may well be imagined. But for Subba Row his life's mission of curing diseases was of supreme importance and all other considerations secondary. He continued his work on phosphocreatin and obtained his Ph.D. in 1930. He did once seriously attempt to come to India by trying to secure a coveted position in the All India Institute of Hygiene and Public Health in Calcutta. But the British found unpalatable the idea of any high scientific position going to Indians (in India!) and gave it to one of their countrymen (who promptly left for England five years later when he secured a good position there).

Subba Row next took up the challenge of pernicious anaemia. It was to take several years of effort to solve. A vitamin, extracted from pig liver, B₁₂, was to prove effective against it. This set off a world-wide search for more vitamins, yielding a rich harvest in the subsequent years. Even apart from his other contributions, Subba Row's name will live on as a trail blazer in the field of vitamins.

Subba Row came to realise that the giant pharmaceutical firms offered a greater scope for research than universities. Accordingly he moved over in April 1940 to the world-renowned Lederle Laboratories at Pearl River in New York State. He naively offered to work at half the salary that they offered him if they would satisfy all his research requirements. But William Brown Bell, a Quaker and the chief of Lederle, was too great a gentleman to exploit him. He gave Subba Row both the salary promised and the facilities he desired!

Subba Row still had a score to settle with the tropical sprue, the killer of his two brothers. It was no easy task to pin down the elusive and tenacious disease. But finally he triumphed through Folic Acid, which he synthesised after a Herculean effort. The memory of the family tragedy would at last haunt him no more.

Filariasis is a disease that is not only debilitating but also affects the victim's self-esteem since it causes grotesque swelling of the legs in its final stages. The disease was prevalent in India and Subba Row had been witness to its ravages. The cure he found was diethyl carbamazine, still the most effective cure for this degrading disease. Alexander Fleming had noticed quite accidentally in 1928 the power of the mould Penicillin to destroy germs. His report of the observation and his attempts (unsuccessful) to produce it in quantity led another team some years later, led by Dr. Howard Florey, to finally develop ways of mass producing it. The golden age of "antibiotics" was born. Subba Row was too perceptive to miss the message. He organised in the laboratory a systematic search and evaluation of the wide variety of moulds available in nature. It was a work of monumental drudgery but it paid off spectacularly. It resulted in the development of Tetracyclines, one of the most widely used broad-spectrum antibiotics of today. During the plague epidemic in Gujarat a few years back, this was the medicine most sought after and most effective (history records the fact that plague, then grimly named Black Death wiped out more than a third of Europe's population in the outbreak of the thirteenth century).

Subba Row was constantly raising his sights and his next targets were nothing less than cures for polio and cancer. One of the medicines he developed, Teorpterin, proved effective against one type of cancer, Leukemia. But these tasks were too big for even

Subba Row. Further more, though he was not aware of it, his own end was around the corner.

On the morning of Monday, 9 August 1948 his associates noticed that Subba Row had not turned up for work. Since he was known to be an obsessive workaholic this was very unusual and they were worried. When they opened his apartment and went in they found him dead. He had been felled by a massive heart attack. This too was a surprise since he had never complained of any of the well-known symptoms of heart trouble. He was cremated as per the desire of his family and the ashes scattered on seas and rivers.

Thus came to a premature close {he was only 53 years old} an extraordinarily focused life. For Subba Row finding cures for dreaded diseases was the only thing that mattered in life. He never visited India for a quarter of a century after he left her shores. But he chose to remain an Indian citizen to the end. Even the long and painful separation that his wife had to endure was, in his eyes, something that had to be accepted since he was serving a higher cause. Money and fame mattered little to him. He felt that diseases were his personal enemies to be fought and conquered for the tragedies that they inflicted on countless families like his own. And he did achieve considerable success in this fight.

The fact that Subba Row did his work abroad and his own self-effacing nature led to his countrymen being largely unaware of his contributions. But gradually the significance of his work is being realised. The Indian government honoured him by releasing a commemorative stamp on the occasion of his birth centenary on 12 January 1995.

However, the best tribute that Indians can pay Subba Row is for more of young Indian men and women emulating his example by serving their countrymen.

9.

K. S. Krishnan

Sealing Wax and String Research

Lords Rama and Krishna are two of the best known characters in our mythology. By an amusing coincidence two of the most prominent Indian scientists of modern times bore the same names, Prof. C.V. Raman and Dr K.S. Krishnan. However, unlike their mythological namesakes, these two were contemporaries and close associates too. Prof. Raman himself once compared their association to that of Bowen-Millikan in the cosmic ray field.

Kariamanikkam Srinivasa Krishnan (K.S. Krishnan for short) was born on 4 December 1898 in the village of Watrap in the Tirunelveli district of Tamil Nadu. His father was a scholar well versed in Tamil and Sanskrit. Krishnan had his early schooling in his village and the nearby town of Srivilliputtur. College education followed in American College of Madurai during the period 1914-1916 and then in the Madras Christian College from 1916 to 1918, where he won the degree of BA.

For the next two years Krishnan served as a Demonstrator in Chemistry in the Madras Christian College. But his heart was really in scientific research. Prof. C. V. Raman was already a name to reckon with and in July 1920 Krishnan went over to Calcutta to enrol for the M.Sc. Course in the University College of Science, where Raman was teaching. However, he was more intent on working under Raman and hence left the course and

joined him in November 1923 as a research scholar in the Indian Association for the Cultivation of Science. He worked on the molecular scattering of light and X-rays in liquids. Another problem that interested him was the magnetic anisotropy of gaseous molecules and crystals.

In October 1928, Prof. Arnold Sommerfeld of Germany delivered a series of lectures on Quantum Mechanics at the Calcutta University. Krishnan carefully studied the lectures and later prepared a booklet on it, which impressed Sommerfeld very much. Thereafter, Krishnan never lost his interest in Quantum Physics and kept himself up to date on the subject.

Krishnan's work in the last part of his collaboration with Raman proved vital. His experiments, under Raman's direction, established the famous Raman Effect for which Prof. Raman was awarded the Nobel Prize in 1930. Raman himself generously acknowledged the contribution of Krishnan in the final stages leading to the discovery of the Raman Effect. On Prof. Raman's recommendation, the Madras University in 1927 conferred on Krishnan the M.Sc. degree.

In December 1928, Krishnan moved to Dacca University as a Reader in Physics. His colleagues there included Satyendra Nath Bose and an old friend Dr T. Vijayaraghavan, Reader in Mathematics. The congenial atmosphere delighted Krishnan and he went to work with great enthusiasm. Since he had to use simple methods he developed experimental methods that a foreign friend of his described as "Sealing Wax and String" methods. He did extensive work on the magnetic properties of diamagnetic and paramagnetic crystals. In recognition of his contributions Madras University conferred the D.Sc. degree on him.

In 1933 Krishnan came back to Calcutta, which was then the scientific capital of India and took up the position of Mahendralal Sircar, Professor of Physics in the Indian Association for the Cultivation of Science. He continued his work on the magnetic properties of materials. In particular his work on graphite was very significant. He was elected a Fellow of the Royal Society, a high honour for a scientist. The outbreak of war with Japan in December 1941 disturbed Calcutta life greatly. There was the possibility of academic institutions and research laboratories being closed down. So Krishnan accepted the offer of a Professorship in Allahabad University.

Dr Krishnan had to spend a lot of time on administrative matters in Allahabad and hence his experimental work suffered. But since he was equally good in theoretical work too he turned his attention to developing the formula for the resistivity of metals and alloys and along with a colleague, Bhatia, succeeded in the task. He was knighted in 1946 and a few months before Independence he moved to Delhi to take up the position of the Director, National Physical Laboratory (NPL).

In independent India, Krishnan had to devote a lot of his time to organisational and administrative matters since they were now the responsibility of Indians. Apart from being the Director of NPL, he functioned as a member of the Atomic Energy Commission and took a major part in organising the International Geophysical year in India in 1957-58. He was awarded the Padma Bhushan in 1954 and the S.S. Bhatnagar Award in 1957.

But Dr Krishnan still managed to devote some time to his research. His field was now thermionics that is the study of electron emissions of heated metals. He and his associates established a procedure to determine the thermionic constants of metals.

Dr Krishnan passed away due to a heart condition on 14 June 1961.

As a person Krishnan was gentle and generous by nature. He had a marked sense, of humour. Pandit Nehru once remarked that he had never met Krishnan without being told a new story! He was a keen follower of cricket and himself played tennis. As one with a deep knowledge of science he was disturbed by its destructive capability and took active part in peace movements. He used to declare that while it was good to have the strength of a giant it is barbarous to use it like a giant.

Above all, Dr Krishnan, as his mentor Prof. C.V. Raman had done earlier, proved to Indian scientists by his example that it was possible to do excellent scientific work with very simple and -inexpensive tools. India badly needs more Krishnans in her present situation.

10.

Homi Jehangir Bhabha

The Father of the Indian Nuclear Programmes

It is strange that the two fields in which India is most highly regarded by the scientific and technological community of the world, Nuclear Power and Space Rockets are the ones in which foreign collaboration has been minimum. In fact, often these two fields have had to be developed in the teeth of the hostile manoeuvring and embargoes of foreign powers. But the efforts of these obstructers proved to be a blessing in disguise. Challenged and thrown back on their own devices, Indian scientists and technologists rose to the occasion and built up these fields to heights highly envied by many nations. Among the developing nations none can match our levels of achievement in these fields.

Many have been the pioneers in this effort but as far as Nuclear Energy is concerned the name of Homi Jehangir Bhabha has got firmly fixed in the public consciousness as the founder of this field in India. Scions of wealthy families often fail to make the best of themselves since they are “born with a silver spoon in the mouth”. Bhabha was a shining exception to this tendency. His family was rich, educated and related to the renowned Tatas. But this background did not dull Bhabha into complacency. In fact, right from boyhood his range of interests was so wide, encompassing science, music, painting etc. that he had to consciously restrain himself and concentrate on one chosen field and accord the others the status of hobbies.

Born on 30 October 1909 into a wealthy Parsee family of Bombay, Bhabha was surrounded from childhood by a profusion of books and distinguished people. The family counted among its friends Gandhiji, the Nehrus and Tatas. This helped kindle in him an intellectual drive and a taste for a wide variety of subjects. It also infused in him a strong nationalist streak and desire to see his country the equal of the West in science and technology. After schooling he entered Caius College, Cambridge University in 1927 to study engineering. He obtained the Mechanical Sciences Tripos in 1930. This

technological background was to stand him in good stead later when he switched over from pure science to the building up of India's nuclear energy establishments.

Bhabha's interest now shifted to pure science. The 1930's were an exciting period in physics. The unfolding of the mysteries of the atom took place at a breathtaking pace. Niels Bohr, Werner Heisenberg, James Chadwick, Enrico Fermi and a galaxy of other brilliant minds engaged in this work were to become household names. Bhabha could not be expected to be unlured by such a field. He plunged into research with enthusiasm and published his first scientific paper in October 1933. It concerned cosmic rays, a field on which he was to leave his indelible mark. The landmark paper came in 1937, in which he and the German physicist W. Heitler developed the "Cascade Theory" of cosmic rays. These are charged sub-atomic particles, originating from non-solar space sources and travelling at very high speeds, close to that of light. When they enter our atmosphere they interact with the air and cause a secondary shower of particles. The mechanism of this cascading effect was not well understood. Bhabha and Heitler put forward the theory of "pair production" to explain it better. The highly energetic electrons of the cosmic rays, according to this explanation, on reacting with nuclei of the atoms in the atmosphere release a pair of electrons, which then go on to repeat the process, thus called "cascading" until the energy of the cosmic rays is absorbed. This work brought Bhabha to the attention of the scientific community as a research worker of the highest order.

But there is also a portion of the cosmic rays which does not produce a shower. These particles penetrate right through the atmosphere and deep into seawater too. In a paper published in 1938 Bhabha postulated that they were composed of "heavy electrons", with a mass one hundred times that of the normal electron. This was later confirmed and named "muons". Bhabha also predicted a slow down in the decay rate of muons with increasing velocity. This too was later experimentally confirmed and constituted one of the best proofs for Einstein's Theory of Relativity. Bhabha's contributions in the 1930's were sufficient, as his co-worker Heitler declared to secure him a permanent place in the history of physics.

With his varied interests Bhabha was never in danger of becoming a single-track mind. In England he actively pursued hobbies like painting, music and sports. In this respect he was very different from most great scientists. In fact, so great was his thirst to pursue different fields that he remained a bachelor for life, avoiding the heavy investment of time and effort that raising a family demands.

Bhabha had no intention of settling down in the West, as he could so easily have done. The central drive of his life was to help raise India to the scientific levels of the advanced nations. For him this was not only necessary for strengthening the country but also for increasing the self-esteem of the Indian people, psychologically burdened by centuries of foreign rule. In 1939 Bhabha returned to India and took up the post of Reader in the Indian Institute of Science, Bangalore in 1940. A couple of years later he became Professor of Cosmic Ray Research. In the year 1941 he was elected a member of the Royal Society of London.

Bhabha firmly believed that an elite institution was necessary to build up a corps of highly competent Indian scientists from which the nation can draw its scientific leaders. Using his eminence he persuaded the house of Tatas to found such an institution, which is

today world-famous as the Tata Institute of Fundamental Research (TIFR). Fittingly, he became its first Director in 1945.

The attainment of our Independence in 1947 changed the picture for Indian Science dramatically. At the helm of affairs now were Indians eager to see India become a scientific power and not a colonial regime unwilling to see subject people become their equals. Bhabha's personal closeness to the first Prime Minister of India, Pandit Jawaharlal Nehru also helped. Bhabha became the first Chairman of the India Atomic Energy Commission founded in 1948. While Bhabha had been a great scientist earlier it was for his contributions as a scientist-administrator after this appointment that India is most indebted to him. Prime Minister Jawaharlal Nehru, sharing an identical view with Bhabha on the need to build up indigenous capabilities in science and technology, gave him plenty of resources and a free hand in using them.

Bhabha made the fullest possible use of the opportunity given to him. He built up the Trombay Atomic Energy Establishment near Bombay to serve as the nucleus of India's efforts in this field. He lovingly took part in every aspect of its planning and execution including even its gardens! The first tow-power "swimming pool" reactor named APSARA was built and went "critical" (that is, a nuclear reaction that is self-sustaining) in August 1956.

Bhabha also arranged for a systematic survey of the natural resources of the country relevant to nuclear energy. These included uranium, thorium, graphite etc. Realising the importance of instrumentation in this field (since no country was likely to provide it easily to us) Bhabha built up an extensive instrument design and production unit which now is known as the Electronics Corporation of India Limited (ECIL).

Bhabha took a leading part in the Geneva Conference of 1955 on Nuclear Energy. He impressed on the developed nations the importance of nuclear power generation for the third world nations. The government of Canada offered to give India a nuclear reactor designed by them, designated NRX. It is noteworthy that by now Indian scientists were producing the fuel for nuclear reactors by themselves; a feat which western experts thought was beyond them. A Nuclear Reprocessing Plant was also set up.

Since nuclear power generation was high on the priorities of Bhabha, power generation reactors were set up at Tarapur and Kalpakkam. These establishments also served as research and training centres. He also helped in setting up a high energy cyclotron, a research tool for nuclear scientists, with completely indigenous design and fabrication.

Bhabha was able to build up these huge establishments essentially without "raiding" our universities for their faculty. He drew mainly from Indian scientists studying or working abroad and also through training programmes in the Atomic Energy Commission itself. Though full of drive and confidence he had the patience to listen to fellow scientists in his organisation and the grace to change his opinion when he found their arguments convincing.

His achievements drew a shower of awards on Bhabha. He was elected a Fellow of the Royal Society in 1941 awarded the Hopkins prize in 1948, the Padma Bhushan in 1954 and countless honorary doctorates. But what must have given him the greatest satisfaction was to be remembered as the Father of Nuclear Energy in India. The

direction and thrust that he gave it in the crucial years has been well utilised by the subsequent generation of Indian scientists to place India firmly among the leaders in this field. Our recent nuclear tests and acquisition of Nuclear power status would have been impossible but for the facilities developed by Bhabha and the people he gathered and trained in the nuclear establishments.

At the height of his career Bhabha's life was snatched away when the plane he was travelling in crashed on Mont Blanc in France on 24 January 1966. The country was of course unfortunate in losing his further services but also had much to be thankful for what he had already achieved.

11.

S. Chandrasekhar

His Eyes were on the Stars

"Astrophysics", "Celestial Mechanics" - the very mention of these subjects evokes visions of great scientists like Galileo, Newton, and Einstein etc. in the mind of the average person. Such is the awe and respect that these great minds command for revealing the complexity of the universe that we live in. As Henry James, the famous psychologist once remarked, but for such minds capable of seeing beyond the obvious, common sense would make average people believe even today that the earth is flat and that it is the sun that goes round the earth.

An Indian-born scientist who belongs to this exalted group is Dr S. Chandrasekhar whose contribution to Astrophysics won him the Nobel Prize for Physics in 1983. A recent satellite launched by the USA to study X-ray radiations in space was named "Chandra", the name by which Chandrasekhar was known among his students and associates.

Chandrasekhar was born on 19 October 1910 in Lahore (now in Pakistan) as the third child of Sri C. Subrahmanya Iyer, a brother of Sir C.V. Raman. Sri Iyer, who worked as an Accountant General for the Government, had a keen interest in music. After initial tutoring at home, Chandra joined the Hindu High School in Madras. He went on to study B.A. (Hons) in Physics at the Presidency College, Madras. He was an outstanding student and his teachers and fellow students could easily discern that he was destined for great things. He published his first scientific paper "Compton scattering and the new statistics" in the Proceedings of the Royal Society at the age of 18. Before he completed his undergraduate studies in 1930 he had published two more papers in the "Philosophical Magazine". Such brilliance could not go unnoticed and he was offered a Government of India scholarship to do research in England. Chandra hesitated to take it up since his mother was then seriously ill but she solved the problem by insisting that he go to England and make use of the opportunity. For her, the greater satisfaction lay in her son becoming famous than in his being by her side to the end. She passed away some months later and Chandra was not to see India again for six years. But he did not disappoint his mother's expectation for him. He rose to the very pinnacle of his field.

On the voyage to England (no Jumbo Jets in those days!), Chandra gave serious thought to an astronomical problem. How does a star (our sun is a medium-sized star) finally end? His work on this subject was to become his best-known work to the general

public. After extensive work over the next several years the conclusion he reached was: stars smaller than 1.44 times the solar mass end up as “White Dwarfs”. Bigger ones explode as Super Novae and depending on their size end up as Neutron Stars or Black Holes (in which the gravitational pull is so high that not even light can escape out of them). This limit of 1.44 times the solar mass has come to be known as the “Chandrasekhar Limit”.

During the years 1930-36, Chandra worked in the Cambridge University under Prof. Ralph H. Howler on this problem. In 1933 he obtained his Ph.D. and was elected a Fellow of Trinity College. He was invited to present his results in the January 1935 meeting of the Royal Astronomical Society. Here he ran into unexpected trouble. Sir Arthur Eddington, the world famous astronomer not only severely criticised Chandra’s conclusions but even ridiculed it. Chandra, taken aback by the fierce attack, defended his theory strongly. But Eddington’s towering stature ensured that a young research worker’s word would not be so easily accepted against his opinion. For many years thereafter, both stoutly defended their positions until finally practical observations settled the issue in Chandra’s favour. But Chandra retained a high regard for Eddington all his life.

In November 1935 Chandra sailed to the USA and delivered lectures at the University of Chicago. He was invited to join the University in its Yerkes Laboratory. He decided to take it up after a visit to India.

In July 1936 Chandra set sail to a motherland he had not seen for many years. While there he married Lalitha, a neighbour of early years. The marriage was remarkable for those times on account of two facts. It was not an arranged marriage. The two young people had decided to join their lives on their own. Further, Lalitha was a graduate and had worked as a school head-mistress before the marriage.

In October 1936 Chandrasekhar again sailed to England on the way to the USA. He joined the University of Chicago in early 1937, being posted to its Yerkes Laboratory. Revelling in the conducive work atmosphere there he rose rapidly in position, becoming an Associate Professor in 1942 and a full Professor in 1944. In the early 1950’s he became more closely associated with the main University at Chicago. In 1953 he and his wife became American citizens.

Apart from his research work, Chandra’s devotion to his students became legendary. In 1946, he used to drive, once a week, a distance of 250 kilometres from his observatory to Chicago to teach a class of two students! But he knew exactly what he was doing. The two students, both of them Chinese, went on to get the Nobel Prize for Physics in 1957.

Chandrasekhar’s way of working was rather unique. He believed that after some years the mind becomes stale and rigid if one is working in the same narrow field. Hence every decade or so he would change the subject of his research, master it, make original contributions to it and then sum up the entire subject by writing a definitive book on it. Other Physicists often wondered how he was able to change direction so often and still remain highly productive. But as they say, the proof of the pudding is in the eating. It is a fact that Chandrasekhar continued to make original contributions to all the fields he touched until the very end. He believed in hard, systematic work. And he was prepared to make the sacrifices necessary for it. He once ruefully remarked that he had always wanted to read all of Shakespeare’s plays in the original but never found the time for it. According to him, great men are seldom born; they have to achieve it through their sweat.

The first major field Chandrasekhar took up in the USA was Stellar Dynamics, which deals with the evolution of galaxies. In the 1940's he moved on to Radiative Transfer and Stellar Atmospheres. This subject deals with the passage of radiation through a star's atmosphere. The book that he wrote summing up the state of the subject "Radiative Transfer" has been his most widely used publication. During the war years (1941-1945 for the USA) He also worked on weapons development for the "US Army. In the 1950's he worked on hydrodynamic and hydromagnetic stability. He paid particular attention to the study of turbulence, an enormously complicated natural phenomenon. He then moved on to the equilibrium and stability of rotating liquid masses. By the 1960's better equipment was leading to exciting discoveries in astronomy such as pulsars and quasars. But what was observed had to be also theoretically explained. Hence Chandra turned his attention to the General Theory of Relativity, which provides the best available explanation on the nature of gravitation, light etc. One of the predictions of this theory is the existence of black holes, where a collapsed star of unimaginable density sucks in nearby matter and prevents radiation from leaving its own core. Chandra's studies on this subject were summarised in his book "The Mathematical Theory of Black Holes", published in 1983. He continued to work on this subject till his death on 21 August 1995.

Chandrasekhar is an example of a scientist totally dedicated to his profession. He once declared that his first loyalty was to Science. He gave up much to satisfy his thirst for scientific research. Actually he was a multi-faceted personality, with a keen interest in music, literature, travelling etc. But to have spent time on them would have meant less time for his main purpose in life. Hence he unhesitatingly chose to devote almost every waking hour to his work. Unlike his illustrious uncle Prof. C.V. Raman, he felt it was justified for a scientist to immigrate to countries better equipped to satisfy the needs of his scientific research.

Such total dedication naturally brought its rewards in results and recognition. He was elected a Fellow of the Royal Society of London in 1944, awarded the National Science Medal of the United States (received from President Lyndon Johnson) in 1966, the Padma Vibushan from the Government of India in 1968 and to crown it all the Nobel Prize for Physics in December 1983.

We evidently have to work for the day when gifted men like Chandrasekhar would find it possible to do their best work in India itself. Nevertheless, we can take pride from the fact that one born and educated in this soil could rise so high in the firmament of Science.

12.

Vikram Ambalal Sarabhai

Pioneer of Our Space Programme

As a group scientists generally fare poorly as managers of vast programmes or industries. This probably is inevitable. Scientific research requires an essentially introverted personality, able to totally focus the mind on abstract problems that are incomprehensible to the layman's mind. This is the very antithesis of the successful manager, who has the ability to understand group mentality, direct vast members of men, understand the intricacies of public finance etc.

However, as the well known saying goes, there are some exceptions to every rule. Dr Vikram Ambalal Sarabhai, the founder of India's space effort was a rarity among scientists, one who was also a successful industrialist, founder of pioneering organisations and the coordinator and inspirer of a vast technological effort. Our country certainly benefited by his versatility and energy. But he wore himself out by his multi-faceted activities and passed away prematurely when only 52 years of age. Or did he, as some of his colleagues felt, have a premonition of his early end and endeavour to achieve as much as possible in the time available? We can never know!

Vikram Sarabhai was born on 12 August 1919 in Ahmedabad. His was a family of wealthy industrialists with a keen sense of social responsibility. His early education was in the family's private school, run on Montessori principles, with the stress on development of independent thinking in the child and the stimulation of interest in a wide variety of subjects including music, literature etc. Being the son of a well-known and active family brought him into contact early with famous personalities such as Rabindranath Tagore, J. Krishnamurthy the Nehrus etc.

After schooling Vikram joined the Gujarat College, Ahmedabad, but before he graduated he left India to join St. John's College of Cambridge University. In 1939 he obtained his Tripos in Natural Sciences. The outbreak of World War II forced him to return to India. He went to work under Dr C.V. Raman on cosmic rays in the Indian Institute of Science, Bangalore.

The study of cosmic rays turned Sarabhai's attention inevitably towards space science and technology. This interest was to lie dormant in him until the opportunity to found India's space programme came. While at Bangalore, Sarabhai met and married Mrinalini Swaminathan, a keen student of Bharathanatyam and destined to gain fame in her own right as a dancer. Two children were born to them, a son Karthikeya and a daughter, Mallika.

In 1945, with the war over, Sarabhai returned to Cambridge. He obtained his Ph.D. degree in 1947 with the thesis titled "Cosmic Ray Investigations in Tropical Latitudes". The thesis also included some work on nuclear fission.

Sarabhai came back to India in 1947. Even at this young age he had grand visions regarding the future of science in India and the steps to be taken to realise them. One of these was the establishment of a laboratory where Indian scientists would have the opportunity to do quality research work in India itself. Accordingly, he started the Physical Research Laboratory in Ahmedabad, with Prof. K. K. Ramanathan, an eminent meteorologist as the first director. With growing support from private foundations and the government the institute grew and is today a leading centre of scientific research in India and a monument to Sarabhai's vision and drive. It was his brain child and he was deeply attached to it. During later years, with all his other preoccupations, he would periodically return to this institute to emotionally recharge himself.

For all his keenness for science Sarabhai was no single-track enthusiast. Unusually for a scientist he had good managerial talents. He nurtured the family pharmaceutical firm, Sarabhai Chemicals and made significant contributions to the establishment of this industry in India. Among the other industries he was associated with were the Sarabhai Engineering Group and the Swastik Oil Mills. He was open to foreign collaboration but not to surrendering his initiative to them. He could judge the capacity of his co-workers

quickly and never punished them for failures as long as he was convinced that they were doing their best.

Sarabhai also played a major part in building up the Ahmedabad Textile Industry's Research Association (ATIRA). He helped greatly in transforming this traditional, family-based industry into one keen to adopt modern methods of production and management. Nor was this the end of his achievements in founding organisations. He was involved in the establishment of the Indian Institute of Management (IIM) in Ahmedabad, which today is one of the famous chains of IIMs in the country and highly regarded abroad too. To improve the educational system of the country he started the Group for Improvement of Science Education (GISE). This later became a part of the Nehru Foundation for Development. It is amazing how he found the time and energy to make outstanding contributions in so many fields.

A man of such energy and drive could hardly remain unnoticed. Prime Minister Nehru gave the responsibility of organising space research in India to Vikram Sarabhai in 1962. In this Sarabhai was to make his greatest contribution to the nation. He established a rocket launching station at Thumba in Kerala, very close to the magnetic equator. It was later expanded to a full-fledged Space Science and Technology Centre (today this centre aptly bears the name Vikram Sarabhai Space Research Centre). Another rocket range was established in Sriharikota in Andhra, a Satellite Communication Centre in Ahmedabad and so on. Totally 15 such Centres were developed and came under the name that has done us all so proud. Indian Space Research Organisation (ISRO).

Sarabhai was particularly good in long range planning and could see beyond the immediate problems of a programme to its ultimate benefits. He realised that a strong space programme would lead to spread of education in the country through satellite transmission of educational programme, enable weather to be forecast accurately, locate resources through satellite mapping and many other benefits. Behind all this was also the realisation that the base built up thus could be used to produce military missiles, when the country desired to do so. His vision and efforts have been vindicated by the fact that our present tactical and strategic missile programmes are largely based on the foundations that Sarabhai built up for civilian and scientific use.

Sarabhai had a ten-year programme for Indian space technology development which consisted of developing small sounding rockets (weather rockets), the launching of space satellites devoted to spreading educational programmes and satellites for television and telecommunication (the well-known INSAT series).

With all the work that he had to put in for the space programme, Sarabhai had to also take over as the Chairman of the Atomic Energy Commission due to the sudden death of Dr Homi Bhabha in 1966. He could manage these gigantic tasks because of one great gift he had - the capacity to quickly understand the basics of any complicated scheme or organisation. Like Bhabha he was a strong believer in nuclear energy for power generation. Under him a series of nuclear power stations such as those in Tarapur, Kalpakkam etc. were planned and the work started. But like Bhabha Vikram Sarabhai was also not destined to see the fruits of his labour.

Sarabhai also played a prominent part, in laying the foundation of the electronics industry in India when he was the Chairman of the Electronics Committee.

Sarabhai had definite views on India's development priorities. He spared some of his valuable time to precisely set down in writing his thoughts on a wide variety of subjects including Agriculture, Fisheries, Transportation, Minerals exploitation etc. though he carried no direct responsibility in these fields. He felt it was his duty to express his opinions on these subjects clearly so that policy planner", could consider them before taking a final decision.

Vikram Sarabhai won the gratitude of his nation even during his rather short life. He was awarded the Bhatnagar Memorial Award for Physics in 1962, Padma Bhushan in 1966 and posthumously the Padma Vibhushan in 1972.

Vikram Sarabhai went about his work like a man possessed. He was known to give appointments to people at 3.30 a.m.! He burnt the candle at both ends, determined to achieve his goals in the shortest possible time. But nature imposes its iron limitations and penalises the liberties we take even in a good cause. Sarabhai suddenly passed away due to cardiac arrest on 30 December 1971. The scion of a rich family, who could easily have passed his life in luxurious ease, chose to burn himself up prematurely in the service of his country. India owes an eternal debt to Sarabhai for putting her in the league of the world's great space powers.

13.

Verghese Kurien

Father of the White Revolution

Our country has venerated the cow through the ages. We have the largest cattle population in the world. But does this mean we have a high level of milk yield per animal or a well-developed dairy industry? The answer is unfortunately an emphatic "No". In these respects we are among the least developed nations in the world. In other words, we have quantity but not quality.

Nevertheless, the situation is much better than it was at the time of our Independence and is gradually improving. Through a series of programmes named "Operation Flood" both the milk yield rates and total milk production have been significantly increased. The prime mover behind these programmes is Dr Verghese Kurien, quite aptly called the "Father of the White Revolution".

Verghese Kurien was born on 26 November 1921 in Calicut in Kerala. He studied for the Bachelor of Science (B.Sc.) degree and later for the Bachelor of Engineering (Mechanical) in the Madras University.

He obtained the latter degree in 1943. He next studied at the Technical Institute of the Tatas at Jamshedpur, graduating in 1946.

Shortly before Independence the British government in India offered a number of scholarships for young Indians to study abroad. Kurien applied for it, keen to be trained further in the field of nuclear physics or metallurgy. Instead he was offered Dairy Engineering! Inexorably fate seemed to push him in the direction of his Destiny, whatever his inclinations of the moment might have been.

Kurien studied this subject in the Michigan State-University, USA, obtaining the Master of Science (M.S.) degree in 1948. He returned to India hoping to be offered a job

in the field of his original interest. But he was posted as dairy expert in Anand in Gujarat. He joined, still hoping that somehow he would get a chance to break free and pursue his interest. But there he came into contact with a man who was to change the direction of his life completely and make him a totally committed crusader for the humble dairy farmer of the country. This was Tribhuvan Das a freedom fighter and dedicated social worker. He saw to it that Kurien got all the modern equipment he wanted but equally important, guided him into the world of the Indian dairy farmer, his attitudes, assets and limitations.

It is a sad fact of the economic structure of our country that the actual producers of primary commodities like grains, vegetables^ vegetable oils etc. get only a fraction of the price the customer pays for these essentials of life. The major portion is skimmed off by grasping middle men. The milk industry was no exception to this. But the milk farmers of Gujarat were one of the few to do anything about it. Under the urging of the inimitable Sardar Vallabhai Patel they had formed in 1946 the Khaira District Cooperative Milk Producers' Union. Under Kurien's stewardship it was later to spawn the brand name familiar to all of us, AMUL.

The beginnings of this cooperative were hardly spectacular. A handful of members contributed their small production of milk (about 200 litres a day) to this organisation. But they had a priceless asset in their chairman Tribhuvandas Patel totally dedicated to seeing that the lion's share of the profit in the milk trade went to the dairy farmers and not to the middlemen. A second asset was added by the involvement of Kurien.

Kurien and Patel represented two different aspects of the dairy industry and in the course of time came to understand each other's importance. Patel realised that idealism and social concern alone were not sufficient to ensure success in this field. Scientific knowledge and managerial capability were equally essential. Kurien for his part came to realise that increasing the efficiency of milk production and processing could not benefit the farmers unless the whole effort was also firmly directed to promoting the farmers' welfare.

Kurien gradually fell in love with his work. He came to greatly respect the native wisdom of the simple farmers. For example, Gujarathi farmers traditionally fed cattle with cotton seed mash, of which the dairy scientists thought little. But later research showed that it was full of beneficial "by pass protein" (the farmers of course had never heard of this term!). His growing emotional involvement with them finally led to his decision to devote his life to this field, into which he had almost strayed by accident. Tribhuvandas Patel too played a part by providing him with the modern equipment he wanted, including milk chillers and milk powder plants.

A technically trained mind is also some times a closed mind. Experts in any field can get confined to narrow grooves of thinking. Kurien (himself an expert) came to realise this by personal experience. A foreign expert asserted that buffalo's milk could not be powdered. But since there were too many buffaloes in India for the idea to be given up without a try, Kurien and his associates went ahead with their efforts - and succeeded! The experience made Kurien formulate his half-jestful but entirely justified comment: "Listen carefully to the experts - and then go ahead and do exactly what you feel is right".

Overcoming entrenched vested interests is the hardest part of any effort to help disadvantaged people. Kurien and Patel too did not find this easy. But they were strongly backed by the members of their cooperative, who came to realise that the fight was on

their behalf. Additionally the top political leadership of the country, particularly Prime Ministers Lal Bahadur Shastri and Indira Gandhi supported their efforts greatly. The proximity of a huge urban market for their products, Bombay city, also helped. Gradually the obstacles were overcome by the “enlightened stubbornness” of its leaders and the total cooperation of the members. Its success began to attract the attention of other milk producers in Gujarat and finally the whole country.

Prime Minister Lal Bahadur Shastri, while on a visit to Anand, was so impressed by its working that he requested Kurien to replicate it in the rest of the country. This was the beginning step in the milk revolution that was to sweep the country. In 1965, the National Dairy Development Board (NDDB) was established with Dr Verghese Kurien as the Founder Chairman to stimulate the dairy development on a national scale.

Kurien and his associates formulated an imaginative action plan. In the first place, the four largest cities of India, Delhi, Mumbai, Chennai and Kolkata were linked with 18 of the best milk-producing regions. Producers’ Cooperatives collected the milk from the farmers and directly marketed them, by-passing middlemen. Here the help rendered by the European Economic Community (EEC) to the project must be noted. They donated their surplus milk powder and butter oil, to be sold in India to form the seed capital for NDDB. It gave the all important initial thrust to the venture.

The second phase of the project, named Operation Flood-II, implemented during 1981-85, brought in 290 urban centres into its network. Dairy plants were also set up to convert surplus milk into milk powder, cheese etc. Phase-III, carried out in 1985-1996, covered further regions of the country and also established centres that specialised in improving the quality of the cattle through artificial insemination from superior breeds.

Today the Anand Pattern is followed practically throughout the country. Its basic features are that the cooperatives guarantee to buy all the milk that their members can produce at a mutually agreed price. The cooperative markets the milk and provides expert advice to its farmer members on the care and breeding of cattle. The surplus milk is converted to cheese, milk powder etc. The basic objectives of the cooperatives are to maximise the portion of the price going to the farmer and to improve their livestock by scientific methods.

The improvement in our milk availability since Independence has been quite significant. A large part of the credit for this achievement should go to the inspiring and imaginative leadership of Dr Kurien. Thanks to him and his co-workers India is today the largest milk producer in the world. But it also has to be remembered that our per capita milk consumption is still much lower than that of developed nations. There is still a long way to go.

Delighted by the success of Operation Flood the leaders of the central government brought other primary commodities under the Anand Pattern. In 1979, the Oil Seeds Growers Cooperative was launched. The Salt Farmers’ Society was formed in 1987 and the Fruit and Vegetable Cooperative in 1988. Thus the example set by Kurien through Operation Flood is producing a powerful multiplier effect.

Dr Kurien has definite views on economic development. Mere increase of production is pointless unless it spreads prosperity to the mass of the people. He is all for utilising effective innovations developed abroad but is against accepting handouts which

undermine our will to solve our problems. A vigilant attitude is necessary to protect our interests in international commercial dealings. He points out that advanced Western nations which fervently advocate “free trade” for others protect their own farmers by subsidy and import restrictions. Above all, development must carry the people with it and not be imposed on them by “experts”.

Dr. Verghese Kurien has been honoured by several national awards such as Padma Shri (1965), Padma Vibhushan (1999) and the Krishi Ratna (1986) and international awards such as the Ramon Magsaysay award (1963) and the World Food Prize in 1989.

But perhaps the most valuable contribution that Dr. Kurien has made to the country is the example that he has set for the younger generation. He has demonstrated what a determined and talented individual can achieve while working under Indian conditions.

In the earlier stages of his career Kurien had to repeatedly face the scepticism and contempt of foreign dairy experts who felt that their Indian counterparts were incapable of solving the massive problems plaguing the dairy industry. Kurien used to get infuriated by such attitudes and vowed to prove them wrong — and he did. If more Indian scientists and technologists imbibe his confidence, determination and drive the days of Indians being treated patronisingly will become a thing of the past.

14.

M.S. Swaminathan

His Revolution was Green in Colour

“Any one who can make two grains of corn grow where one grew before is greater than all the monarchs of the world” goes an old saying. It is easy for us today to forget how often our country used to be devastated by famines (the last one, the Bengal Famine of 1943 took three million lives). It is only in the past thirty years that India has enjoyed unbroken self-sufficiency in food production. For this happy state of affairs we owe a great debt of gratitude to agricultural scientists, both foreign and our own. Among the most prominent contributors to our agricultural progress is Dr M.S. Swaminathan, currently the Chairman of the M.S. Swaminathan Research Foundation in Chennai. His career spanning more than four decades has practically coincided with the period of the greatest change ever experienced by Indian agriculture.

Monkombu Sambasivan Swaminathan was born in Kumbakonam, Tamil Nadu on 7 August 1925. His father was an eye-specialist. He had his basic education in Tamil Nadu. After obtaining his B.Sc. from Travancore University in 1944, he took up agricultural science as his speciality and studied the subject in the Coimbatore Agricultural College, obtaining a B.Sc. degree in Agriculture also in 1947.

After a brief stint as a research associate in the Indian Agricultural Research Institute, New Delhi, Swaminathan left on a UNESCO fellowship to Netherlands during 1949-50. He then went on to do his Ph.D. in the school of Agriculture, University of Cambridge, UK, being awarded the degree in 1952. Subsequently he did research in plant genetics at the University of Wisconsin, USA during 1952-53. He returned to India (most of the Indian scientists of those days used to return home after studies abroad!) and served as a research scientist and research manager in the Central Rice Research Institute, Cuttack

and at the Indian Agricultural Research Institute, Pusa, New Delhi during the period 1954-1972.

This was a momentous period in free India's history. The population was rising fast (it still is rising fairly fast) and our agricultural methods were primitive. Our yield rates of almost all crops, rice, wheat, vegetables etc. were a fraction of what advanced nations had achieved. Monsoon rain was the most crucial factor in Indian agriculture. If it failed scarcity and even famine stalked the land. Indian history is replete with records of recurrent famines wiping out millions of people. In the previous centuries this was accepted fatalistically since there was nothing that could be done about it. But for such a situation to exist in the middle of the twentieth century with all its scientific advancements was intolerable and called for strong remedies.

An offshoot of our poor agricultural productivity was a pathetic dependence on foreign handout to prevent famines. In particular, it became a regular feature for our politicians and officials to rush to the USA and plead for accelerated shipments of wheat under the PL-480 programme. A severe crisis arose in 1964-65 due to wide spread crop failures in India.

Nations, like individuals, are susceptible to arm-twisting when they are critically dependent on others. President Lyndon Johnson of the USA was a past master at this game (from his previous experience of managing US congressmen and Senators!). He now taught us a harsh lesson. He delayed the shipment of wheat, causing great anxiety in India, all the while delivering homilies to our politicians and officials on the necessity to manage our country's affairs better. The government was jolted to its roots by this experience. A fierce determination/ arose to avoid such situations in the future by becoming self-sufficient in food production. At this juncture, a helping hand from across the ocean was extended by a remarkable agricultural scientist.

Norman E. Borlaug had obtained his Ph.D. in Agricultural Science from the University of Minnesota in 1941. He was sent to Mexico by the Rockefeller Foundation in 1944 to improve the wheat yields there. He was to spend the next thirty years there. Borlaug was what he himself termed a "dirty-handed scientist", that is one who believed in field work. The basic problem was that if the wheat plant was heavily fertilised and irrigated to increase yields, it became top-heavy with grains and bent over, scattering the grains. The stem had to be made shorter and stronger. The plant also needed to be resistant to diseases, particularly rust. Borlaug spent two decades on this task, crossing and re-crossing different wheat varieties and trying them out. It was work of monumental drudgery. But Borlaug and his associates stuck to it and at last developed a dwarf variety of wheat which would absorb extra nutrients and hold the grains in an upright position. With these strains, Mexican wheat yields increased dramatically in the mid 1960s.

Swaminathan was one of the first to realise the potential of this development. He took the initiative to invite Dr Borlaug to India and try out his wheat varieties on our soil. At first the trials failed but they persisted and finally the right cultivation practices for our conditions were worked out.

Swaminathan was also backed by the imaginative and firm support extended by the then Union Minister of Agriculture, Sri C. Subrahmanyam. The vast network of Indian agricultural extension workers also plunged into the task enthusiastically since they could sense success. In 1967-68, India, in particular Punjab achieved a spectacular increase in

wheat production. What was then called “Wheat Revolution” and later “Green Revolution” was on and was to transform India from being a pathetic pleader for foreign grain shipments to full self-sufficiency in spite of a rapid increase in population. The part played by Dr Swaminathan and other Indian agricultural scientists in this achievement is not to be underestimated. The wheat strains supplied by Borlaug later developed susceptibility to some diseases under Indian conditions and it was the efforts of our agricultural scientists which led to more resistant strains. Also the later increase in rice production was mainly due to the work of our scientists. This was a glorious hour for Indian agriculture and for Dr Swaminathan personally. Dr Swaminathan became known as one of the leading agricultural experts of the world. He became Secretary to the Ministry of Agriculture, Government of India in 1979 and member of the Planning Commission during the period 1980-92.

The International Rice Research Institute is located in Los Banos, Philippines. This premier institution has been responsible for the development of several high yielding varieties of rice. Indian scientists have formed an important part of this institute right from its inception. Dr Swaminathan became the Director General of this institute in April 1982 and held this position for nearly six years.

Dr Swaminathan’s research work has encompassed a wide variety of fields. It includes the nature of the potato plant, effect of radiation on food articles, modification of plant structure to optimise rice and wheat yields, conservation of coastal bio-diversity and the impact of climate change on crop productivity.

Apart from being a top class agricultural scientist Dr Swaminathan has a holistic view of economic development. He sees little point in achieving “jobless growth”. He is a strong advocate of women playing a greater role in economic and educational development. Above all, he is convinced that human society has no future unless it lives in harmony with nature. Rapacious and ruthless exploitation of natural resources and the environment ultimately recoils hardest on humans themselves. We can not survive major catastrophes the way simpler animals can. The key to our survival is “Sustainable Development”. This in a nutshell is his philosophy.

With the resources generated by his awards and from various donor organisations Dr Swaminathan established the M.S. Swaminathan Research Foundation in Chennai in 1989. The main aim of this organisation is to gain knowledge of the interdependence of the different parts of the ecosystem and to evolve Sustainable techniques of agriculture. It supports a wide variety of research activities and the emphasis is on field work. At any point of time, the majority of the research workers are plodding in rice fields and mangrove swamps getting data.

Dr Swaminathan has received a very large number of awards and honorary degrees, not surprising for a person of such eminence. These include the Shanti Swarup Bhatnagar Award (1961), the Padma Shri (1967), Padma Bhushan (1972), the First World Food Prize, the equivalent of the Nobel Prize in the Agricultural field (1987) and the Padma Vibushan (1989). But the greatest source of satisfaction to him should be the fact that during his own career he has seen India graduate from a position of depending on foreign nations to prevent famines to one of being consistently self-sufficient and his own great contribution to it. He believes that India has all the requirements for becoming an agricultural super power. No other nation is blessed with such a wide variety of climates

and plant species. No other country grows both apples and mangoes, tea and coffee, rubber and spices, all within its own territory. It is up to us to make the best of this gift of nature by following the path shown to us by eminent agricultural scientists like Dr M.S. Swaminathan.

15.

A. P. J. Abdul-Kalam

Great Work is Possible in India Too

Advanced Western nations have a fixed idea which has been very difficult to change — the people of developing nations are not capable of great scientific or technological achievements, this occasionally extends even to some European nations. The first nuclear test explosion conducted by the Soviet Union in 1949 came as a shock to most western scientists and politicians who had convinced themselves that the Soviets were incapable of such feats (one American General had sneered late in 1945 that the Russians were incapable of even making Jeeps).

Most people do not realise that the supremacy of the West in Science and Technology is a historically recent phenomenon. Five centuries back, the Chinese and Indian civilizations were superior in science to Europe. The Chinese invented printing and u- d gunpowder first. The zero and decimal system of arithmetic were Indian discoveries. Our ancestors of five or six centuries back could make astronomical calculations far more accurately than Europeans. They had nothing comparable to our textile industry. Hence there is nothing inherent or immutable about the *lead* of the West in science and technology. The future is bound to see the balance shift towards Asia.

Those who hold an advantage are naturally loathe to losing it to others. In keeping with this fact of human nature, advanced nations have tried their best over the past half century to prevent know-how in vital fields such as rockets, nuclear energy and super computers from flowing to developing countries. But history has proved repeatedly that such efforts are futile. Those determined to acquire them would do so by their own efforts, greatly stimulated by such bans. This is what India has done in the two vital fields of nuclear power and rocketry.

For our success in these efforts we owe a great debt of gratitude to our scientists and engineers who have spiritedly risen to the challenge. An outstanding member among them is Bharat Ratna A.P.J. Abdul Kalam. For our achievements in space over the past decade and more he has been the moving spirit. Incidentally his career is also an illustration for the power of determination and effort to overcome great obstacles. He did not have the backing of a wealthy or powerful family and had to face all the deficiencies of our system which Indians settling abroad give as excuses. But unlike them he stayed back and worked his way upto the highest recognition that our nation has to offer.

Avul Pakir Jainulabdeen Abdul Kalam was born on 15 October 1931 in the pilgrim centre of Rameswaram, located at the southern extremity of India. His father owned a few boats that ferried pilgrims. Education did not run in the family. Kalam was the first graduate of the family. His early schooling was in Rameswaram and Ramanathapuram. He was a keen student and a voracious reader in spite of the absence of an academic atmosphere at home. The book collections of his neighbours like Sri S. T. R. Manickam

proved an invaluable source of information and inspiration to him. The whole atmosphere of his boyhood was marked out by excellent communal harmony, an age-old tradition of our land. His family was associated with certain services and honours of the famous Rameswaram temple. Many of the individuals who fed his thirst for knowledge and encouraged him were Hindus.

In 1950 Kalam enrolled himself in the well-known St. Joseph's College in Tiruchirappalli and graduated in 1954, with a B.Sc. degree in Physics. Kalam had been fascinated ever since childhood by rockets and bird flight and hence desired to study aeronautical engineering. However, the family's financial resources did not match his ambition. The problem was solved by his sister pledging her gold bangles and raising the necessary money. She could not have imagined the spectacular results that her sacrifice would produce for the country. Kalam joined the Madras Institute of Technology (MIT), one of the prestigious institutions of engineering education in the country. In those days the number of students of engineering was small and this led to intimate contact between the teacher and student. A good teacher is more than one who passes on his knowledge. More importantly, he inspires the student by personal example and exhortation, something possible only in small groups.

Kalam found the atmosphere in the institution very congenial. The most important characteristic he developed there was self-confidence. He came to believe strongly that it was possible to achieve in India technical feats so far reserved only for the rich developed nations. He was never to consider settling down abroad. There was enough opportunity and plenty of work to be done right at home.

In 1957 Kalam graduated from MIT and joined as a graduate engineer in the Hindustan Aeronautical Ltd. (HAL) at Bangalore. His initial task was the overhauling of aero-engines, piston and gas turbine types. Sometime later, he was selected for the Directorate of Technical Development and Production (Air) in which he worked on supersonic unpiloted target aircraft.

He next took up assignment in the newly-formed Aeronautical Development Establishment (ADE). On his own, he took up the design and development of a hovercraft. This is a type of vehicle that rides on a cushion of air and hence can go over any terrain, water or land, even marshes.

The prototype of this vehicle was ready for testing about a year later. The then Minister of Defence, Sri V.K. Krishna Menon had a ride in it, piloted by Kalam personally. Since it was his brainchild, he possibly had to take responsibility for its performance and safety too! Some time later, Prof. M.G.K. Menon also took a ride in the hovercraft and was so impressed that he got Kalam inducted into the Indian Committee for Space Research (INCOSPAR). Here Kalam came into contact for the first time with Dr Vikram Sarabhai, who laid the foundation for India's space effort (the rocket development centre at Thumba in Kerala has been named after this great son of India).

Kalam was sent for specialised training to National Aeronautical and Space Agency (NASA) in the USA. He spent six months there (the longest period he ever spent abroad!). He was highly impressed by their sophisticated equipment but even more by the systematic and organised way in which Americans carried out their projects. His eye was also specially caught by another item. In one of the major NASA Centres, there hung a large oil painting of Tipu Sultan bombarding the British with rockets in a battle as far

back as 1784. He had seen nothing like it in India, where Tipu fought the British! He realised how sadly we were lacking in national pride, the driving force behind a nation.

Kalam returned to India in November 1963 and went to work developing sounding rockets (which study atmospheric conditions) at Thumba. By stages these solid-propellant rockets were developed to reach a range of 350 kilometres.

Like our nuclear effort, our space effort also had to be developed in the teeth of opposition from advanced Western nations, who had a vested interest in retaining their superiority in this field. Through their tremendous economic and political clout they saw to it that other nations also would not help us in these fields. No equipment or instrument even remotely useful to these programmes was allowed to be sold to us. Everything had *to be* developed by our own scientists and engineers. Sarabhai and other leaders of these projects realised that a very extensive and integrated effort involving propellants, guidance systems and satellite design were needed with close monitoring of the progress.

Kalam's first big break came when he was made the head of the Satellite Launching Vehicle Programme (SLV). It was to prove a great learning lesson also for him in management. On the technical side, these projects have to be well thought out and meticulously planned. On the human side, the leaders of the different groups in the project have to be chosen with great care and once given responsibility must be allowed to function freely. But the leader should be ever ready to help them in case of need. Drawing on the expertise of well-developed research and educational institutions like the CSIR laboratories and IITs accelerated progress. Lastly, none should be blamed if a sincere effort resulted in failure, which was fairly regular in the beginning due to the incredible complexity of the whole system. For example the SLV-3 had nearly a million individual components. Very high reliability of the components was necessary. If our cars were made to the same level of reliability a visit to a mechanic would be unnecessary for more than a decade! The first launch of SLV-3 on 10 August 1979 proved a painful failure, but the lessons learned led to the great success of the next launch in July 1980, by which the satellite ROHINI was placed in orbit,

Kalam's easy and friendly approach was a great asset in organising the effort. He would effortlessly go to a technician in the workplace and learn first hand about his problems and provide him encouragement. No wonder the whole group working under him warmed to this approach and always extended their unstinted support and enthusiasm.

The success of SLV-3 led the political leaders of India to give Kalam an even greater responsibility. He was to plan, organise and execute the Integrated Guided Missile Development Programme (IGMDP) in the Defence Research and Development Organisation (DRDO). In Hyderabad. It consisted of the development of five weapons systems, a surface-to-surface missile (PRITHVI), a tactical missile (TRISHUL), a surface-to-air missile (AKASH), an anti-tank missile (NAG) and an intermediate range missile (AGN1), the last incorporating re-entrant technology also. The effort was to be spread over 12 years with an outlay of nearly Rs. 400/- crores. The two men who played a key note in formulating this bold and imaginative plan were Dr V.N. Arunachalam, the Scientific Advisor to the Defence Minister (Shri R. Venkataraman) and Kalam. Work started in earnest in July 1983.

The next decade, though hectic, was possibly the finest in Kalam's life. All the hard-earned lessons of the previous projects were put to good use now.

The mighty power of a rocket, so awesome to watch during a launch, is however only half the story. To be useful, this brute power has to be delicately and accurately guided by a maze of electronic circuits, the components of which are often too small to be seen by the eye. Decisions regarding course, thrust etc. have to be made far faster than a human brain is capable of and the margin for error is very little. It is hence no wonder that not more than half a dozen nations have mastered the art of military and civilian missiles and satellites.

Powerful nations try very hard to prevent other nations from becoming powerful. This has been a fact of history ever since it began to be recorded. The USA in particular has come up with schemes like MTCR (Missile Technology Control Regime), CTBT (Comprehensive Test Ban Treaty) etc. which outwardly seem very reasonable and idealistic but are really meant to prevent other nations (in particular, developing nations) from becoming their equals in military power. Due to its economic clout the USA is also able to pressurise other nations to back off from agreed commitments to supply us critical equipment in this field. The latest instance is that of the Russians being prevented from supplying us with cryogenic rocket engines. But perhaps it is for the best in the long run since it will stimulate our self-reliance. AGNI was flight tested in May 1989, barely six years after the work on it started a very creditable achievement. The guidance and re-entry technology were also found to be highly satisfactory. Another advanced version of it was tested again in February 1994. It has a range of 2500 kilometres. It can be further converted into an Inter Continental Ballistic Missile (ICBM).

PRITHVI missile has been inducted by the Army. The other three missiles have also been completed or on the verge of completion.

The part he played in our nuclear test explosions of May 1998 are too recent and too well known to be described in detail. His value to the nation can be judged by the fact that even at the age of 69 the national government relies heavily on him, an age at which the average government official has long disappeared into retirement and obscurity!

Dr Kalam strongly believes that the technical spin-offs of our space effort should also benefit the common people more directly. Through the Society for Biomedical Technology (SBMT) this is being done. Doctors and engineers cooperate to develop devices useful to ill and crippled people. The "Kalam-Raju Stent", useful to heart patients, is an example of the fruits of such efforts.

The personal life style of Dr Kalam has been characterised by a discipline and simplicity bordering on austerity. He has been so deeply involved with his profession that he eschewed the luxuries of marriage and raising a family. The fact that he has risen so high in his profession without generating any controversies speaks volumes for his selfless dedication to work, tact and friendliness.

Dr Kalam's contributions have been heartily acknowledged by our nation. He has been showered with honours, the Padma Bhushan in 1981, Padma Vibhushan in 1990 and most recently the highest of all, the Bharat Ratna in 1997. But above all this is a reward he has earned - the satisfaction of helping his country to become stronger and thereby earn greater respect from other nations.

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